IS BITCOIN THE NEW CONFEDERATE MONEY? BY CLIVE THOMPSON

America's Greatest Trees BY ZACH ST. GEORGE

The Thing That Humbled the Godfather of Soul BY RJ SMITH

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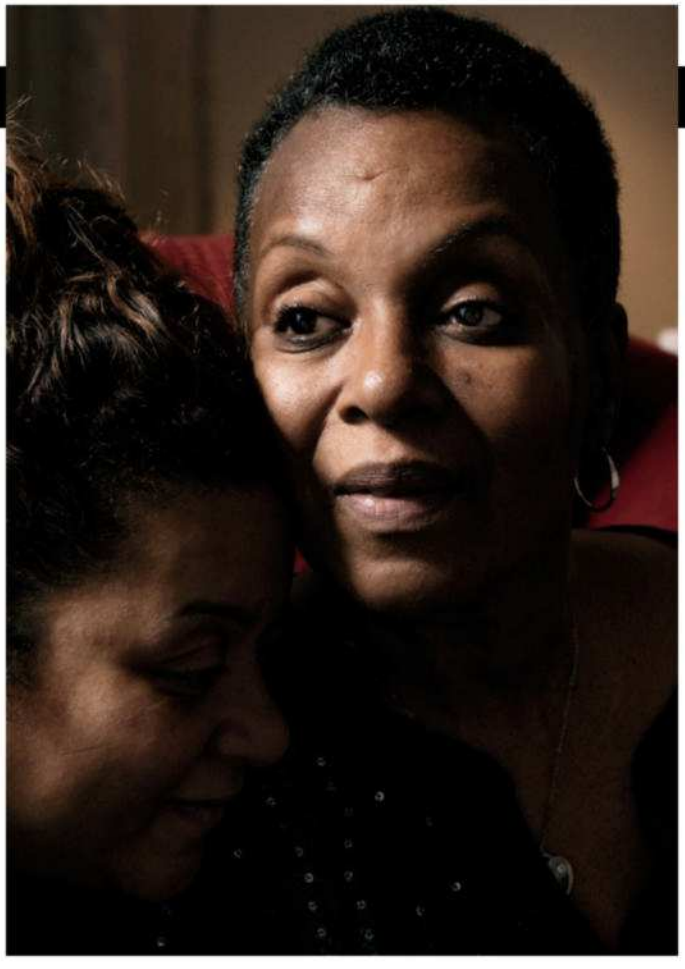

Doctors had given Vanessa Johnson Brandon (with her daughter, Keara Grade) a grim prognosis before she found a clinical trial for a then-experimental treatment.

GREG KAHN

features

prologue

departments

Cover: David Arky created this sudsy composition by taking multiple photographs of a mug of beer through a gridded pane.

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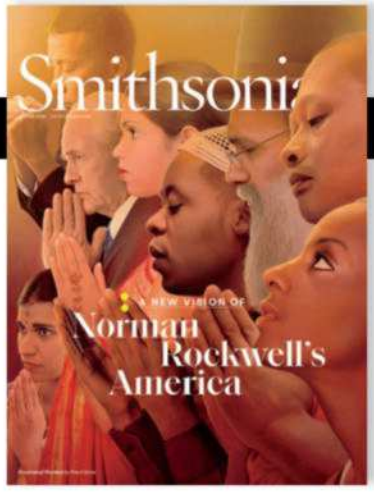

FROM THE EDITORS

TO COMMEMORATE Norman Rockwell's famous Four Freedoms, we commissioned four major artists to create new versions for our time. The images provoked as well as inspired. Joseph H. Shaffer, a retired immigration special agent, objected to Edel Rodriguez's "Freedom from Fear," saying: "To portray children and parents in the United States as living in fear of being ripped from their beds in the middle of the night destined for a shadowy, Nazi-like concentration camp patrolled by soldiers with WWII-era rifles and attack dogs is despicable." But most readers approved of the project. "The question of what the Four Freedoms mean today is a fair one," Donald I. Craig Jr. of Indianapolis noted. Each artist "bravely pointed out idiosyncratic new directions in our dynamic and sometimes struggling democracy," Shelby Morrison of Orlando wrote. "I think Rockwell himself would approve the results."

Hamsters of the Corn

Your article about wild hamsters on farmland in France ("Cereal Killers") discusses the work of Dr. Joseph Goldberger, who discovered that pellagra is caused by a dietary deficiency. What you don't mention was that Goldberger was an officer in the U.S. Public Health Service, a little-known organization whose roots go back to 1798. Today's USPHS officers deploy to the field and fight disease just as Goldberger did. This 6,500-member corps of professionals deserves to have its part in the fight against disease recognized by *Smithsonian*.

— **James T. Currie, Commissioned Officers Association of the USPHS** | Landover, Maryland

Talking Trees

Lincoln Taiz, the retired professor of plant biology, is probably correct that natural selection can explain everything that *he* knows about plant behavior ("The Whispering of the Trees"), but that does not mean natural selection can explain everything there is to know about plant behavior. Peter Wohlleben and Suzanne Simard are showing us that there is a lot more to learn. Blinders are not a useful tool for studying nature; we should not be afraid of what we might see.

— **James A. Schoettler** | St. Paul, Minnesota

As a reclamation scientist, I've conducted studies on trees. In a number of sites, trees grown in circles and clusters survived and thrived while those grown in lines often died or lacked vigor. There is so much to learn from nature.

— **Mary Ann Simonds** | Wellington, Florida

TO SMITHSONIAN MEMBERS

Some members have been receiving "renewal notices" from companies that are not authorized by *Smithsonian*. Many of the notices list a price higher than on an order card in this issue and are called "Notice of Continuation/New Order." Such unauthorized solicitations are an industrywide problem. Any membership renewal or billing notice you receive directly from *Smithsonian* will be mailed from Washington, D.C. or Tampa, Florida. We do have agreements with a few authorized magazine companies to sell subscriptions, and if you have any question or concern about whether an offer you receive by mail or phone is legitimate, please do not hesitate to contact us. Email: Smithsonian.ConsumerAffairs@customersvc.com, phone: 800-766-2149, mail: Smithsonian Magazine, P.O. Box 62170, Tampa, FL 33662-2170

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Robin Marantz Henig

The science writer and former Guggenheim fellow first reported on immunotherapy when it emerged 30 years ago accompanied by a great deal of premature hoopla. When she returned to the subject to write about exciting new developments (p. 44), Henig was inspired to learn that "scientists had been plugging away without a whole lot of support from the mainstream cancer community and without a whole lot of funding." Henig is a contributing writer for the *New York Times Magazine*, an adjunct professor of journalism ethics at New York University and the author of nine books. Her next is a science-based look at grandmotherhood.

Jules Julien

"What will artificial intelligence bring us that we don't expect?" asks the French visual artist, who's based in Amsterdam. He explores the various possibilities, both frightening and exciting, in his illustrations for "Be(a)ware" (p. 34). Envisioning what the future may hold, Julien says his goal is to create artwork that is "easily understandable but avoids using the classical iconography that we are used to seeing on that subject."

Adam Fisher

Raised in Silicon Valley, the writer grew up on a steady diet of video games and computer programming. He explores the history of his hometown and peeks at what its future might hold in his book *Valley of Genius* (due out in July), from which "Tomorrow Land" (p. 56) is adapted. "If you don't understand where the future has been, you have no idea where it's going," he says. Fisher's writing has appeared in *Wired* and *MIT Technology Review*.

David Arky

The still-life photographer "tries to pare down to the most elemental components" when approaching an object for a shoot. For this month's cover, and the illustration accompanying Franz Lidz's "Buzzed Lightyear" (p. 60), that meant deconstructing a frothy glass of brew into its parts and "finding the right ones to tell the story instantly." Known for his conceptual and X-ray photographs, Arky has taught at the International Center of Photography in New York since 2001.

RJ Smith

"I couldn't think of a more interesting artist from the 20th century to write about and to try to understand than James Brown," Smith says of the subject of his 2012 biography *The One: The Life and Music of James Brown* , which was nominated for an NAACP Image Award. He revisits the legacy of the groundbreaking, culture-defining musician in "Make It Funky" (p. 24). Smith's most recent book is about another iconic American artist: *American Witness: The Art and Life of Robert Frank*.

Kotryna Zukauskaite

The Lithuanian artist has been illustrating technology columns for *Smithsonian* since 2015. She's attracted to the special challenge they pose because they are both "relatable and mind-blowing." She says, "I see value in illustrating complex technological and scientific concepts into visually relatable images." Her newest accompanies "In Bitcoin We Trust" (p. 13).

Stephan Talty

Interviewing scientists and scholars about artificial intelligence (p. 34) left Talty "alternating between wonder and terror at how it's going to change the world." He was happy to conclude that people still have some control in shaping their future: "We're going to get the AI that we plan for." Talty's next book, *Saving Bravo: The Greatest Rescue Mission in Navy SEAL History*, will be out in October.

Illustrations by **Marina Esmeraldo**

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THE PAST IS

prologue

AMERICAN ICON

By
Zach St. George

The towering, 2,500-year-old "Mother of the Forest" (second from left) died after its bark was stripped for display in New York in 1855.

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Tall Tales

California's Giant Sequoias tell the story of our conflicted relationship with nature

AMERICAN ICON

IN THE WINTER OF 1852, while chasing a wounded grizzly bear in the mountains of eastern California, a hunter named Augustus T. Dowd encountered a very large tree. It had red-orange bark and clouds of sea-green needles, and it would've taken more than a dozen men with outstretched arms to encircle it. When Dowd told his campmates what he'd found, they laughed. Then he took them to see the tree.

Newspapers trumpeted the discovery, calling the find—long known to Native Americans—"the Sylvan Mastodon" and "the Vegetable Monster." Soon, another group of men returned to Dowd's tree and, perhaps inevitably, cut it down. Everybody counted the rings on the felled trunk differently—one reporter estimated it to be 2,500 years old, another 4,000 and a third 6,500. "It must have been a little plant when Samson was slaying the Philistines," one wrote.

In fact, the tree in question was only about 1,200 years old, relatively young for one of the earth's longest living and largest species. The astounding trees we now know as giant sequoias can live for more than 3,000 years and grow to some 300 feet, and the superlative species inspired this young, growing nation like no other living thing. That it is rare and limited in its range—the tree lives in only about 70 groves in the middle elevations of the Sierra Nevada—made it all the more fascinating. For more than 150 years, the "noblest tree-species in the world," as the great naturalist John Muir called it, has been a symbol of America's grandeur, our fraught relationship with nature and our fears about the future.

The nation had only recently seized California from Mexico when Dowd made his discovery, and the ancient giants were the upstart nation's answer to the Old World's cathedrals. California, one 1853 article predicted, "will yet be found not only to surpass the rest of the world in the extent and abundance of her gold and the magnitude of her trees, but in her natural bridges, her mammoth caves and her Niagaras."

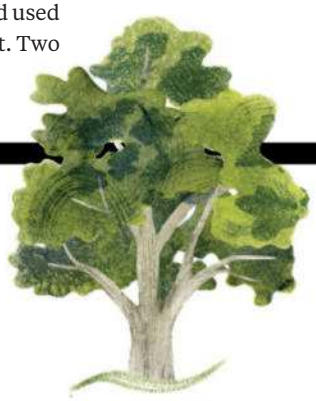
"Big Tree mania" set in, William Tweed writes in a 2016 history of the giant sequoia. Pieces of Dowd's tree went on tour to San Francisco and to New York City. By 1855, a hotel had been built in the grove. Later, promoters cut a wide passage in the base of one giant and charged for carriage rides through it. Souvenirs proliferated—candlesticks and canes turned from sequoia wood, packets of sequoia seeds, hotel postcards and stereoscope images. A collection of giant sequoia memorabilia, recently acquired by Stanford University, serves as a snapshot of the country's obsession and the impulse to cash in on it.

Timbermen toppled the giant sequoias, one by one, and then by the groveful. By the end of the 19th century, the American frontier was closed, the herds of buffalo and the great flocks of passenger pigeons were gone, and some feared the magnificent trees would disappear, too. Nature could be used and used up. But the idea of conservation had taken root. Two

Landscape

Into the Woods

SOME OF THE UNITED STATES' 228 BILLION TREES ARE DOING BETTER THAN OTHERS. THE RISE AND FALL OF OUR MOST BELOVED VARIETIES



WHITE OAK
Quercus alba
Region: Eastern and Central United States

In demand for bourbon barrels, it's healthy overall, but arborists worry about oak wilt, a preventable disease that reached still farther north in 2017.

AMERICAN CHESTNUT
Castanea dentata
Region: Eastern United States

Just over a century ago, some four billion of these commercially valuable trees flourished; today the species is nearly extinct, wiped out by a fungal blight. Scientists are sequencing the genome of the few survivors to find clues about why they were spared.

WIKIMEDIA, FRANCE (CONE DETAIL)

of the first three national parks were created to protect the sequoias.

Such rescue attempts had unintended consequences. Early conservationists suppressed fires, which they thought damaged the sequoias. In truth, the trees needed nature's regular, low-burning blazes to thin their competition and to clear ground for their seedlings. Decades of fire suppression left the groves packed with vegetation that could fuel bigger, more damaging fires, like the one that swept into Kings Canyon in 2015, killing approximately ten large sequoias. Grove managers have worked to return the habitat to a more natural state since the 1960s but say many sequoia groves remain overgrown and at risk.

> **"GOD HAS CARED FOR THESE TREES, SAVED THEM FROM DROUGHT, DISEASE, AVALANCHES, AND A THOUSAND STORMS."**

Our fascination with these giants hasn't diminished since the days of Big Tree mania. In 2014, more than a million people visited the Mariposa Grove in Yosemite National Park, home to approximately 500 giant sequoias. Vehicles and parking lots and concrete paths were encroaching on the trees' habitat. The grove was closed in 2015 for restoration; it will reopen this spring.

But there is a problem more insidious than sneaker-clad tourists: climate change. In 2014, after two years of drought, many sequoias began losing their needles. Nobody alive had ever seen this before. It seemed like another sign of the times, a losing struggle to save even the rarest and best of things. "In 50 years, the whole population could be in trouble," one researcher told the *New York Times*.

When the snows and rains came in 2017 and ended the drought, the sequoias were still standing. The trees, it now seems, had shed their needles as a way to reduce their need for water. Last summer, the needles began to grow back, and with them our hopes for the sequoias. But with temperatures rising and weather patterns changing, their future is as uncertain as it was in Muir's day. "God has cared for these trees, saved them from drought, disease, avalanches, and a thousand storms," he wrote in the early 1900s. "But he cannot save them from sawmills and fools; this is left to the American people." ◆

LODGEPOLE PINE

Pinus contorta

Region: Western United States

Bark beetles, their range apparently boosted by climatic warming, are attacking this favored source of utility poles, but scientists say the ever-adaptable conifer may be evolving a defense: a sticky sap to trap the voracious pests.

WHITE BIRCH

Betula papyrifera

Region: Northern and Central United States

Already under pressure from drought, disease and competition from other trees, the white birch is also threatened by its own popularity. Demand for the wood in home décor has led to illegal harvesting in Wisconsin and Minnesota.

SUGAR MAPLE

Acer saccharum

Region: Eastern and Central United States

In recent years, warmer, drier growing seasons have stunted the growth of young sugar maples and may shrink the cold-loving trees' range. One potential effect: a long-term maple syrup shortage.

QUAKING ASPEN

Populus tremuloides

Region: Almost all of the United States, except the Southeast

Famed groves in Colorado began to die in 2004, and scientists now say the cause was thirst from drought, a recurring problem. Some predict that 50 percent of the aspen's current range will be too hot and dry for the trees by 2060.

AMERICAN ELM

Ulmus americana

Region: Eastern and Central United States

Dutch elm disease has killed an estimated 77 million trees since 1928, but disease-resistant cultivars have been identified and field tests are underway to encourage cities to again line their streets with the magnificent shade tree.

DOUGLAS FIR

Pseudotsuga menziesii

Region: Western United States

This major source of building material—and half the country's Christmas trees—has suffered recent bark beetle outbreaks, which damaged tens of thousands of acres and contributed to 2017's record-breaking lumber prices.

Illustrations by **Hannah Bailey**

ART

By **Amy Crawford**

FINDING DORA

The artist best remembered as Picasso's muse steps out of his shadow

IN THE EARLY 1930s, Dora Maar (1907-1997) was a leading Surrealist photographer whose daring darkroom experiments hung in Paris galleries alongside the work of Man Ray and Salvador Dali. "She was exploring psychology and dreams and inner states," says Erin O'Toole, a curator at the San Francisco Museum of Modern Art, where Maar's *Double Portrait* (above, c. 1930s) is appearing in a new group show. Maar's soaring career faltered after she met Pablo Picasso in 1935. She modeled for him—she was the famed "Weeping Woman"—and became best known as his lover and muse. Picasso, no fan of photography, persuaded her to close her studio, and after their relationship ended, Maar could not regain her former fame. "All his portraits of me are lies," she would later say. "They're all Picassos. Not one is Dora Maar." Those Cubist canvases are no longer the final word on Maar now that her own creations—mysterious, groundbreaking—are again hanging alongside the greats. ◆

▲ Maar's Surrealist work is on display at SFMOMA and will be featured at Paris' Centre Pompidou and L.A.'s Getty Center in 2019.

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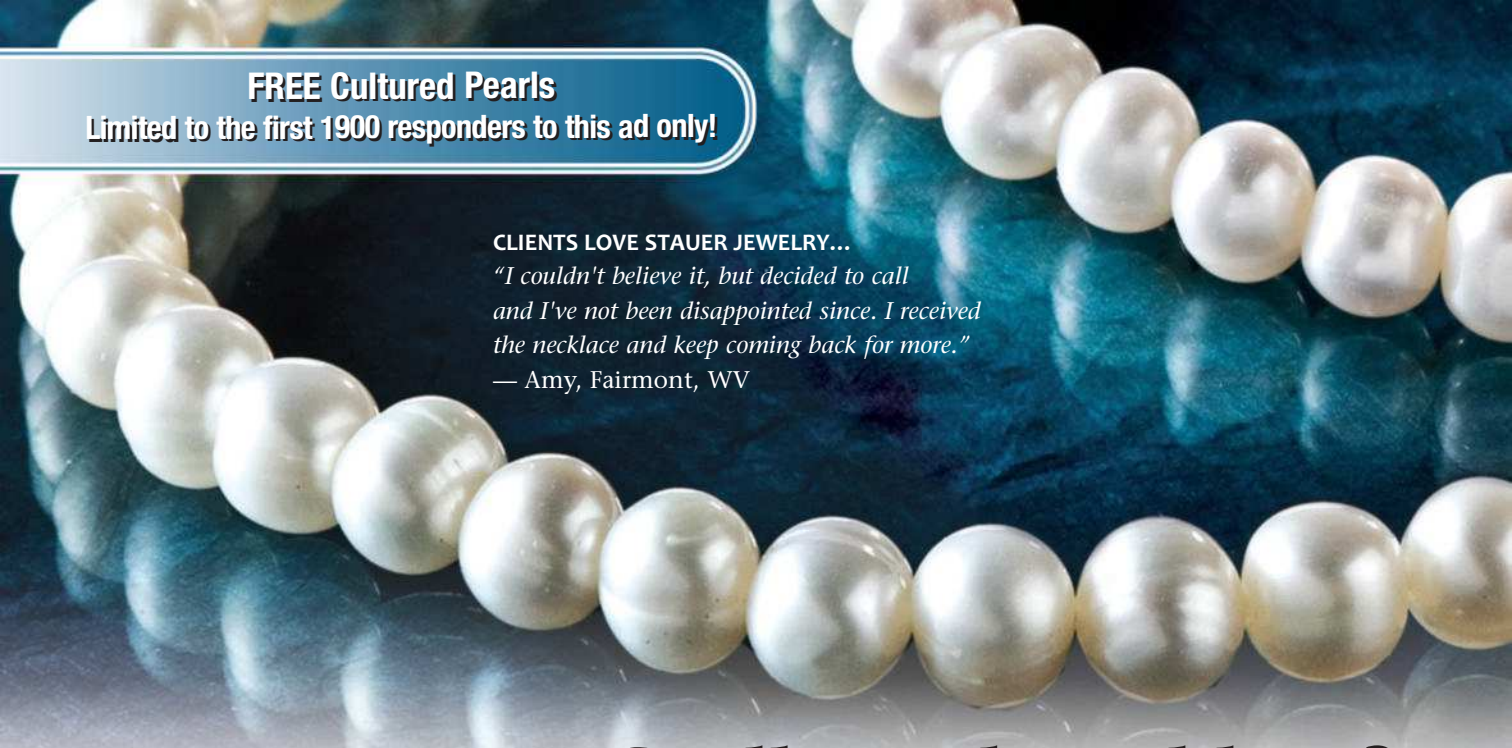

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TECHNOLOGY

By
Clive Thompson

Illustration by
Kotryna Zukauskaite

In Bitcoin We Trust

What Benjamin Franklin and Jefferson Davis can teach today's cryptocurrency creators

IF YOU WALK INTO the Ketchup Premium Burger Bar in Las Vegas, tucked inside you'll find a strange icon of today's economy: a Coinsource ATM. Put in a few American dollars, and the ATM will quickly exchange them for Bitcoin, the newfangled digital currency, which it will place in your "digital wallet." Want to do the reverse transaction? No problem: you can sell Bitcoin and withdraw U.S. greenbacks.

Bitcoin, as you may have heard, is poised to overturn the world of currency. That's because it's a form of digital cash that adherents regard as unusually robust. Bitcoin is managed by a community of thousands of "miners" worldwide who are running the Bitcoin software, each of them recording every single transaction that takes place. This makes Bitcoin transactions extremely hard to fake: If I send you a Bitcoin, every single one of those "mining" computers records that transaction, so you cannot later claim you *didn't* receive it. Similarly, I can prove I own 100 Bitcoin because every mining computer affirms this.

It's the first global currency, in other words, that people feel secure enough to own—yet isn't controlled by any government.

And it's making some Bitcoin holders massively wealthy—at least on paper. "We got in early, jumped with both feet," says Cameron Winklevoss, a high-tech entrepreneur who, with his twin brother, Tyler, bought millions of dollars of Bitcoin when a single digital coin was worth under $10. By the end of 2017, Bitcoin had soared to almost $20,000 per coin, making the Winklevosses worth $1.3 billion in the virtual dough. But Bitcoin is also wildly volatile: Mere weeks later, its value plunged in half—shaving hundreds of millions off their fortune.

It hasn't fazed them. The Winklevoss twins,

who won $65 million from Facebook in a lawsuit claiming the business was their idea, believe Bitcoin is nothing less than the next incarnation of global money. "This was something that was previously not thought possible," Cameron says. "They thought that we need central banks, we need Visa, to validate transactions." But Bitcoin shows that a community of people can set up a currency system themselves. It's why Bitcoin's earliest and most ardent fans were libertarians and anarchists who deeply distrusted government control of money. Now they had their own, under no single person or entity's control!

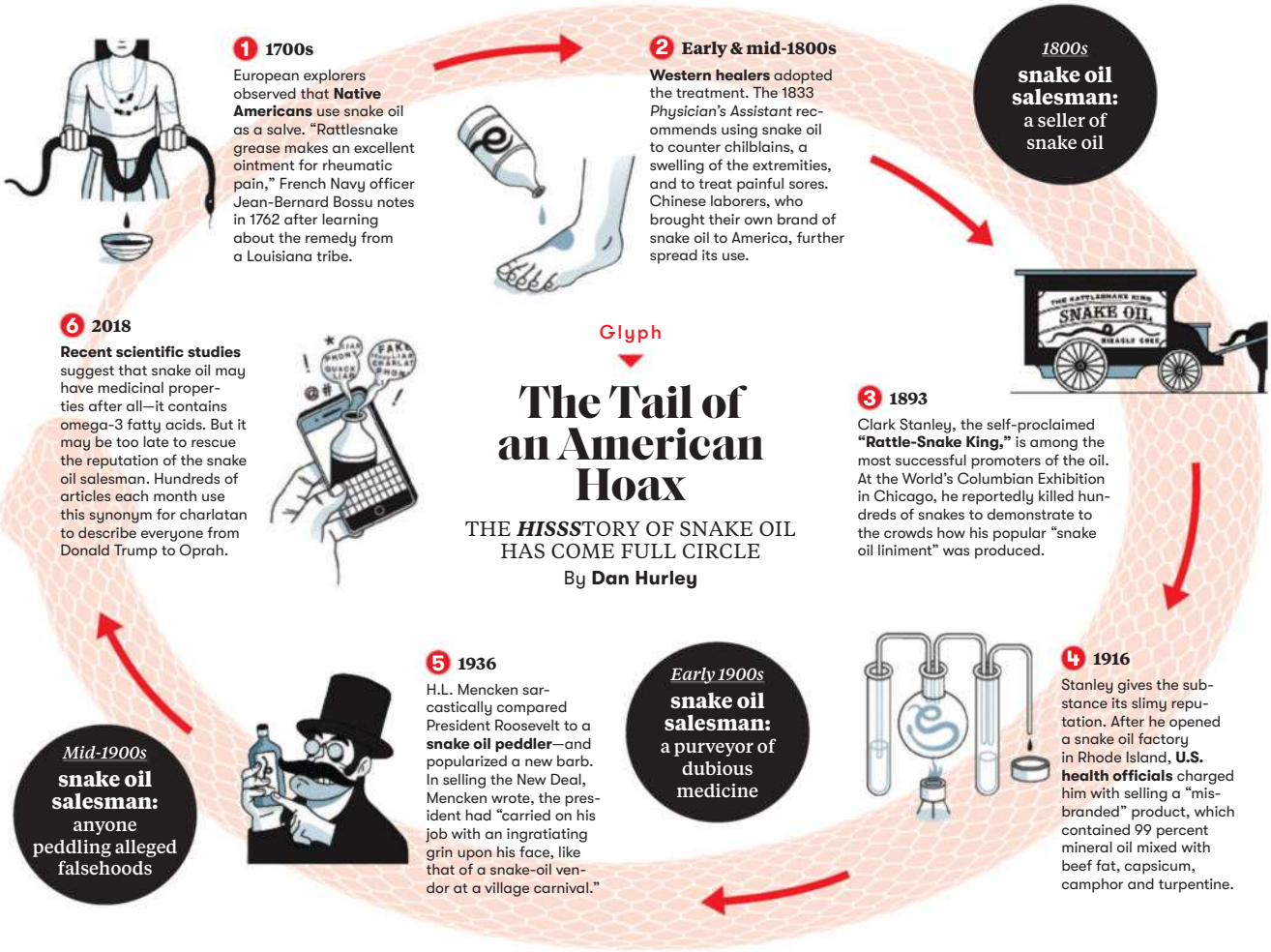
Nor is Bitcoin alone. Its rise has set up an explosion of similar "cryptocurrencies"—companies and individuals who take open-source blockchain code freely available online and use it to issue their own "alt-coin." There's Litecoin and Ether; there are start-ups that raised tens of millions in just a few hours by issuing a coin avidly bought by fans who hope it, too, will pop like Bitcoin, making them all instant cryptomillionaires.

Though it's hard to fix a total, according to CoinMarketCap there appear to be more than 1,500 alt-coins in existence, a global ocean of digital cash worth likely hundreds of billions. Indeed, the pace of coin-issuing is so frantic that alarmed critics argue they're nothing but Ponzi schemes—you create a coin, talk it up and when it's worth a bunch, sell it, leaving the value to crash for the Johnny-come-lately suckers.

So which is it? Are Bitcoin and the other alt-coins serious currencies? Can you trust something that's summoned into being, without a government backing it?

As it turns out, this is precisely the conundrum that early Americans faced. They, too, needed to create their own currencies—and find some way to get people to trust in the scheme.

CURRENCIES ARE THOUSANDS of years old. For nearly as long as we've been trading goods, we've



Illustrations by **Harry Campbell**

wanted some totem we can use to represent value. Ancient Mesopotamians used ingots of silver as far back as 3,000 B.C. Later Europe, too, adopted metal coins because they satisfied three things that money can do: They're a "store of value," a "medium of exchange" and a way of establishing a price for something. Without a currency, an economy can't easily function, because it's too hard to get everything you need via barter.

The first American Colonists faced a problem: They didn't have *enough* currency. At first, the Colonists bought far more from Britain than they sold to it, so pretty soon the Colonists had no liquidity at all. "The mind-set was, wealth should flow from the Colonies to Britain," says Jack Weatherford, author of *The History of Money*.

So the Colonists fashioned their own. They used tobacco, rice or Native American wampum—lavish belts of beaded shells—as a temporary currency. They also used the Spanish dollar, a silver coin that was, at the time, the most widely used currency worldwide. (The terminology stuck: This is why the government later decided to call its currency the "dollar" rather than the "pound.")

A young Ben Franklin decided that the United States needed more. He'd noticed that whenever a town got an infusion of foreign currency, business activity suddenly boomed—because merchants had a trustworthy, liquid way to do business. Money had a magical quality: "It is Cloth to him that wants Cloth, and Corn to those that want Corn," he wrote, in a pamphlet urging the Colonies to print their own paper money.

War is what first pushed the Colonies to print en masse. Massachusetts sold notes to the public to fund its battles in Canada in 1690, promising that citizens could later use that money to pay their taxes. Congress followed suit by printing fully $200 million in "Continental" dollars to fund its expensive revolution against Britain. Soon, though, disaster loomed: As Congress printed more and more bills, it triggered catastrophic inflation. By the end of the war, the market drove the value of a single Continental to less than a penny. All those citizens who'd traded their goods for dollars had, in effect, just transferred that wealth to the government—which had spent it on a war.

"That's where they got the phrase, 'not worth a Continental,'" says Sharon Ann Murphy, professor of history at Providence College and author of *Other People's Money*.

Some thought it was a clever and defensible use of money-printing. "We are rich by a contrivance of our own," as Thomas Paine wrote in 1778. Government had discovered that printing dough could get them through a rough patch.

But many Americans felt burned and deeply distrustful of government-issued bucks. Farmers and merchants were less happy with fiat currency—not backed up by silver or gold—because of how the often-inevitable inflation wreaked havoc with their trade.

This tension went all the way to the drafting of the Constitution. James Madison argued "nothing but evil" could come from "imaginary money." If they were going to have currency, it should only be silver and gold coins—things that had real, inherent value. John Adams hotly declared that every dollar of printed, fiat money was "a cheat upon somebody." As a result, the Constitution struck a compromise: Officially, it let the federal government mint only coins, forcing it to tether its currency to real-world value. As for the states? Well, it was OK for financial institutions in the states to issue "bank notes." Those were essentially IOU's: a bill that you could later redeem for real money.

FIGURING OUT WHICH BILL TO TRUST WAS HARD—A DAILY CALCULATION FOR THE AVERAGE AMERICAN.

As it turns out, that loophole produced an avalanche of paper money. In the years after the Revolution, banks and governments across the U.S. began avidly issuing bank notes, which were used more or less as everyday money.

Visually, the bills tried to create a sense of trustworthiness—and Americanness. The iconography commonly used eagles, including one Pennsylvania bill that showed an eagle eating the liver of Prometheus, which stood in for old Britain. They showed scenes of farming and households. The goal was to look soothing and familiar.

"You had depictions of agricultural life, of domestic life. You get portraits literally of everyday people. You got depictions of women, which you don't have today on federal bills!" says Ellen Feingold, curator of the national numismatic collection at the Smithsonian's National Museum of American History. "You got pictures of someone's dog." All told, there were probably 9,000 different bills issued by 1,600 different banks.

But figuring out which bill to trust was hard—a daily calculation for the average American. If you lived in New Hampshire and someone handed you a $5 bill issued by a Pennsylvania bank, should you trust it? Maybe you'd only CONTINUED ON PAGE 86

By
Franz Lidz

Mid-1900s specimens collected in Latin America by Alfred Russel Wallace include parrot wings and marsupial pelts.

The Great Feather Heist

The curious case of a young American's brazen raid on a British museum's priceless collection

OF ALL THE ECCENTRICS cataloged by "Monty Python's Flying Circus," the most sublimely obsessive may have been Herbert Mental. In a memorable TV sketch, the character zigzags through a scrubby field, furtively tracking something. Presently, he gets down on all fours and, with great stealth, crawls to a small rise on which a birder is prone, binoculars trained. Sneaking up behind him, Mental stretches out a hand, peels back the flap of the man's knapsack and rummages within. He pulls out a white paper bag, examines the contents and discards it. He pulls out another bag and discards it, too. He reaches in a third time and carefully withdraws two hard-boiled eggs, which he keeps.

As it turns out, Mental collects eggs. Not bird eggs, exactly. Birdwatchers' eggs.

BRIDGEMAN / NATURAL HISTORY MUSEUM LONDON

The British generally adore and honor eccentrics, the barmier the better. "Anorak" is the colloquialism they use to describe someone with an avid interest in something most people would find either dull (subway timetables) or abstruse (condensed matter physics). The term derives from the hooded raincoats favored by trainspotters, those solitary hobbyists who hang around railway platforms jotting down the serial numbers of passing engines.

Kirk Wallace Johnson's new book *The Feather Thief* is a veritable Mental ward of anoraks—explorers, naturalists, gumshoes, dentists, musicians and salmon fly-tyers. Indeed, about two-thirds of the way through *The Feather Thief*, Johnson turns anorak himself, chasing down stolen 19th-century plumes as relentlessly as Herbert Mental stalked the eggs of birders. Johnson's chronicle of an unlikely crime by an unlikely crook is a literary police sketch—part natural history yarn, part detective story, part the stuff of tragedy of a specifically English kind.

The anorak who set this mystery in motion was Alfred Russel Wallace, the great English biologist, whose many eccentricities Johnson politely sidesteps. What piqued my curiosity and prompted a recent trip to London was that Wallace, a magnificent Victorian obsessive, embraced spiritualism and opposed vaccinations, colonialism, exotic feathers in women's hats, and unlike most of his contemporaries, saw native peoples without the gaze of racial superiority. An evolutionary theorist, he was first upstaged, then totally overshadowed, by his more ambitious colleague Charles Darwin.

Beginning in 1854, Wallace spent eight years in the Malay Archipelago (now Malaysia and Indonesia), observing wildlife and paddling up rivers in pursuit of the most sought-after creature of the day: the bird of paradise. Decked out in strange quills and gaudy plumage, the male has developed spectacular displays and elaborate courtship dances whereby he morphs into a twitching, lurching geometric abstraction. Inspired by bird of paradise sightings—and reputedly while in a malarial fever—Wallace formulated his theory of natural selection.

By the time he left Malay, he had depleted the ecosystem of more than 125,000 specimens, mainly beetles, butterflies and birds—including five species from the bird of paradise family. Much of what Wallace had accumulated was sold to museums and private collectors. His field notebooks and thousands of preserved skins are still part of a continuous voyage of discovery. Today the vast majority of Wallace's birds repose at a branch of the Natural History Museum, London, located 30 miles northwest of the city, in Tring.

The facility also houses the largest zoological collection amassed by one person: Lord Lionel Walter Rothschild (1868-1937), a banking scion said to have almost exhausted his share of the family fortune in an attempt to collect anything that had ever lived. Johnson pointed me to a biography of Rothschild by his niece, Miriam—herself a world authority on fleas. Through her account, I learn that Uncle Walter employed more than 400 professional hunters in the field. Wild animals—kangaroos, dingoes, cassowaries, giant tortoises—roamed on the grounds of the ancestral pile. Convinced that zebras could be tamed like horses, Walter trained several pairs and even rode to Buckingham Palace in a zebra-drawn carriage.

At the museum in Tring, Lord Rothschild's menagerie was stuffed, mounted and encased in

Origins

Nabbing Nest Robbers

LONG BEFORE EDWIN RIST entered the museum in Tring, Mervyn Shorthouse absconded with some of its eggs. Ten thousand of them. In 1975, Shorthouse, who posed as disabled and kept to his wheelchair prop, was allowed to visit the museum's vaults on compassionate grounds—he said he had been disfigured in an electrical accident and was unable to work. Over the next four years he dropped in regularly, ostensibly to study the prodigious collection of bird eggs—pierced and the contents blown out to preserve delicate casings.

Alone in the archives, Shorthouse carefully stuffed eggs into socks, secret pockets sewn into his overcoat and women's tights with slit knees worn under his trousers. "A sting operation by suspicious staffers finally led to his arrest," author Kirk Wallace Johnson says.

Eggers, as the illegal collectors are called, often scale tall trees or abseil down cliffs to raid nests. Egg pillaging was rampant until 2001, when prison became a sentencing option. Since then 14 eggers—all men—have been locked up, the most persistent being the four-times jailed Matthew Gonshaw.

In 2012, the unemployed Londoner had his wings clipped for plundering the nests of Britain's rarest species, including golden eagles and black-tailed godwits. "Gonshaw was motivated by trophies and the thrill of the chase," says Mark Thomas, a senior investigations officer for the Royal Society for the Protection of Birds. "His rationale was twisted. He'd say, 'It's not like I'm killing birds. I'm just taking their eggs.'" If only! The eggs he went after in the wild are rarely infertile. Gonshaw sometimes snatched eggs so late in their incubation that he removed developing chicks from the shells.

Gonshaw, banned from entering Scotland during breeding season, says he's controlling his compulsion by practicing yoga. —F.L.

ALAMY (3)

floor-to-ceiling displays in the gallery, along with bears, crocodiles and—somewhat disconcertingly—domestic dogs. The collections house nearly 750,000 birds, representing about 95 percent of all known species. Skins not on show are socked away in metal cabinets—labeled with scientific species names organized in taxonomic order—in storerooms off-limits to the public.

Which brings us back to Johnson's book. During the summer of 2009, administrators discovered that one of those rooms had been broken into and 299 brightly colored tropical bird skins taken. Most were adult males; drab-looking juveniles and females had been left undisturbed. Among the missing skins were rare and precious quetzals and cotingas, from Central and South America; and bowerbirds, Indian crows and birds of paradise that Alfred Russel Wallace had shipped over from New Guinea.

In an appeal to the news media, Richard Lane, then director of science at the museum, declared that the skins were of immense historical importance. "These birds are extremely scarce," he said. "They are scarce in collections and even more scarce in the wild. Our utmost priority is working with the police to return these specimens to the national collections so that they can be used by future generations of scientists."

At the Hertfordshire Constabulary, otherwise known as the Tring Police Station, I was given the low-down of what happened next. Fifteen months into the investigation, 22-year-old Edwin Rist, an American studying the flute at London's Royal Academy of Music, was arrested at his apartment and charged with masterminding the heist. Surrounded by zip-lock bags jammed with thousands of iridescent feathers and cardboard boxes that held what remained of the skins, he confessed immediately. Months before the break-in, Rist had visited the museum under false pretenses. Posing as a photographer, he cased the vault. A few months later, he returned one night with a glass-cutter, latex gloves and a large suitcase, and broke into the museum through a window. Once inside, he rifled through cabinet drawers and packed his suitcase with skins. Then he escaped into the darkness.

In court, a Tring constable informed me, Rist admitted that he had harvested feathers off many of the stolen birds and snipped the identifying tags off others, rendering them scientifically useless. He'd sold the gorgeous plumes online to what Johnson

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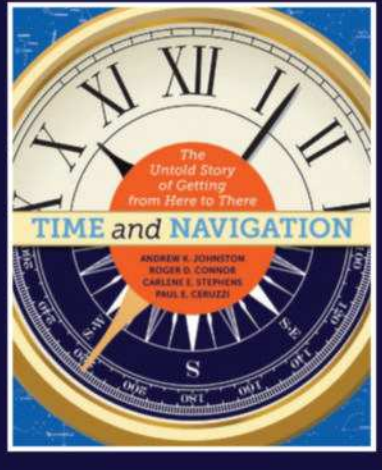

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calls the "feather underground," a flock of zealous 21st-century fly-tyers who insist on using the authentic plumes called for in the original 19th-century recipes. While most of the feathers can be obtained legally, there's an extensive black market for the tufts of species now protected or endangered. Some Victorian flies require more than $2,000 worth, all wound around a single barbed hook. Like Rist, a virtuoso tyer, a surprising percentage of fly-tyers have no idea how to fish and no intention of ever casting their prized lures to a salmon. An even greater irony: salmon can't tell the difference between a spangled cotinga plume and a cat's hairball.

In court, in 2011, Rist sometimes acted as if the feather theft was no big deal. "My lawyer said, 'Let's face it, the Tring is a dusty old dump,'" Rist told Johnson in the only interview he has granted about the crime. "He was exactly right." Rist claimed that after about 100 years "all the scientific data that can be extracted from [the skins] has been extracted."

> **"THESE SKINS HOLD ANSWERS TO QUESTIONS WE HAVEN'T YET THOUGHT TO ASK. WITHOUT THEM, YOU LOSE THOSE INSIGHTS."**

Which is not remotely true. Robert Prys-Jones, the retired former head of the ornithology collection, confirmed to me that recent research into feathers from the museum's 150-year-old seabird collection helped document rising heavy-metal pollutant levels in the oceans. Prys-Jones explained that the capacity of skins to provide both new and important information only increases over time. "Tragically, the specimens still missing as a result of the theft are vanishingly unlikely to be in a physical state, or attached to data, that would make them of continuing scientific utility. The futility of the use to which they have probably been put is deeply sad."

Though Rist pleaded guilty to burglary and money laundering, he never served jail time. To the dismay of museum administrators and the Hertfordshire Constabulary, the feather thief received a suspended sentence—his lawyer argued that the young man's Asperger's syndrome was to blame and that the caper had merely been a James Bond fantasy gone wrong. So what became of the

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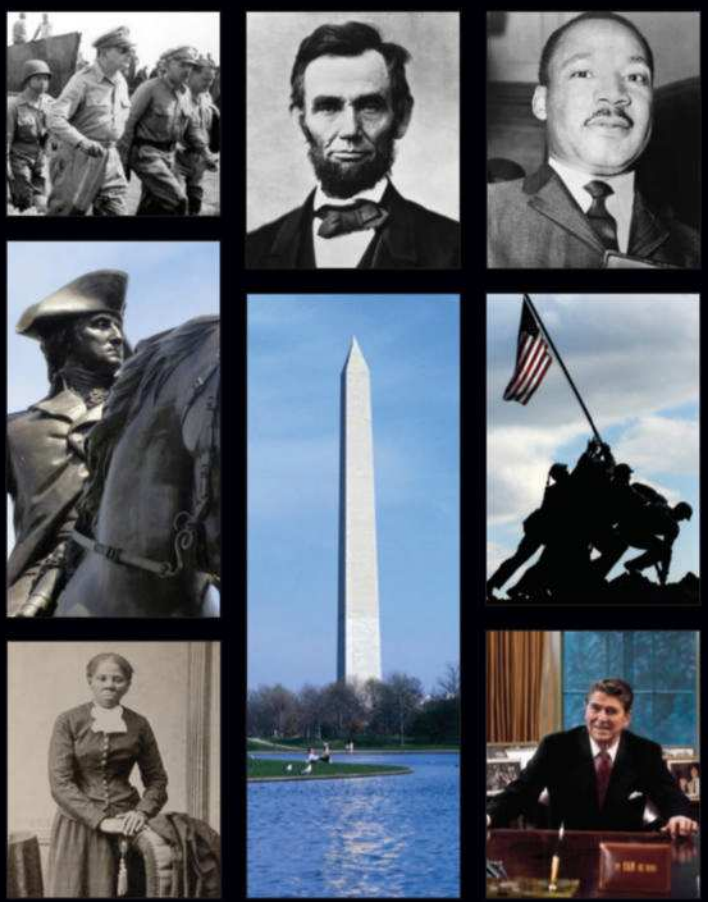

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NATURAL HISTORY

tens of thousands of dollars Rist pocketed from the illicit sales? The loot, he told the court, went toward a new flute.

A free man, Rist graduated from music school, moved to Germany, avoided the press and made heavy-metal flute videos. In one posted to YouTube under the nom de plume Edwin Reinhard, he performs Metallica's thrash-metal opus *Master of Puppets*. (Sample lyric: "Master of puppets, I'm pulling your strings / Twisting your mind and smashing your dreams.")

NOT LONG AGO I caught up with Johnson, the author, in Los Angeles, where he lives, and together we went to the Moore Lab of Zoology at Occidental College, home to 65,000 specimens, largely birds from Mexico and Latin America. The lab has developed protocols that allow for the extraction and processing of DNA from skins that date to the 1800s. The lab director, John McCormack, considers the specimens—most of which were gathered from 1933 to '55—a "snapshot in time from before pristine habitats were destroyed for logging and agriculture."

We entered a private research area lined with cabinets not unlike the ones at Tring. McCormack unlocked the doors and pulled out trays of cotingas and quetzals. "These skins hold answers to questions we have not yet thought to ask," said McCormack. "Without such specimens, you lose the possibility of those insights."

He opened a drawer that contained an imperial woodpecker, a treasure of the Sierra Madre of northwest Mexico. McCormack said timber consumption partly accounts for the decline of this flamboyant, two-foot-long woodpecker, the world's largest. Logging companies viewed them as pests and poisoned the ancient trees they foraged in. Hunting reduced their numbers, too.

Told that he had shot and eaten one of the last remaining imperials, a Mexican truck driver reportedly said it was "*un gran pedazo de carne*" ("a great piece of meat"). He may have been the final diner. To paraphrase Monty Python's Dead Parrot sketch: The imperial woodpecker is no more! It is an ex-species! Which might have made a splendid Python sketch if it weren't so heartbreaking. ◆

Archaeology

Dogged Pursuit

CANINES MAY SOON BE ON THE FRONT LINES IN THE FIGHT AGAINST ARTIFACT SMUGGLING

By **Christine Speer Lejeune**

Grizzly, a detection dog in training, is learning to sniff out stolen antiquities.

AT THE UNIVERSITY OF PENNSYLVANIA, Roxie, Moxie, Pacy, Scout and Grizzly are ready for their first archaeology class. The pupils—four Labradors and a German shepherd—each take a turn with a trainer in a quiet room to focus on the task at hand: sniffing cotton that had been sealed in a bag with bits of ancient Syrian pottery, and then getting a treat.

At the Penn Vet Working Dog Center, researchers have taught dogs to detect bombs, drugs, arson, people, even cancer. But this is the first time dogs are learning to recognize the smell of artifacts. The goal is to reduce the smuggling of archaeological treasures from Syria and Iraq, where looting has skyrocketed as a source of funding for terrorist groups.

The K-9 Artifact Finders project is a collaboration with Penn's Museum of Archaeology and Anthropology and Red Arch Cultural Heritage Law and Policy Research, a nonprofit trying to stem the trafficking. "How do you keep these smuggled cultural artifacts from crossing borders without searching every shipment, every suitcase?" asks Ricardo St. Hilaire, the executive director of Red Arch. The K-9 initiative was his idea, a way to see if detection dogs can curb trafficking at airports, seaports and other places stolen antiquities slip through security.

After the dogs learn to identify the scent of the artifacts, they will be tested for sensitivity, says WDC director Cynthia Otto. Can canines smell the difference between pottery pieces that have sat in a museum for years and those that are recently excavated—and thus more likely to have been looted from an archaeological site? Do antiquities from Syria smell the same as ones from Iraq?

A couple of weeks after their first sniff, all the canines in this inaugural class recognize the odor of the pottery. Moxie has caught on especially quickly. Circling a steel disk with compartments hiding various items—rubber gloves, paper, plain cotton—she stops suddenly at the one containing the pottery-scented cotton and noses it enthusiastically. "Woo-hoo!" the trainer trills. Tail wagging, Moxie trots over to get a small bite of hot dog, then continues her training as a soldier in the war on terror.

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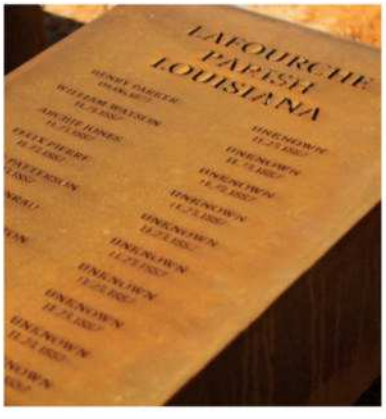
By
Matthew Shaer

NECESSARY TRUTHS

A new memorial remembers the thousands of African-Americans who were lynched

IN THE EARLY MONTHS of 1904, a black man named Luther Holbert was accused by neighbors in Doddsville, Mississippi, of killing a white farmer. Holbert was never given a chance to stand trial. Instead, he and an unnamed female companion were chased dozens of miles across Sunflower County before they were captured, tied to a tree, tortured with corkscrews and knives, and burned alive. Although hundreds of people observed the double lynching—according to newspaper reports, the crowd dined on deviled eggs, whiskey and lemonade—no monument was erected to remember the brutally murdered man and woman and no charges were ever brought against their killers.



The names of 50 victims of the 1887 Thibodaux massacre in Louisiana are among those inscribed on the new memorial.

Now Holbert's name is finally being etched into history—along with those of 4,400 other lynching victims—at the National Memorial for Peace and Justice, which opens this month in Montgomery, Alabama. It's the first monument to the lynching campaign that terrorized black residents of the South and Midwest for more than 80 years. Created by the Equal Justice Initiative, a legal advocacy group led by the lawyer and author Bryan Stevenson, the memorial sits on a grassy hilltop in the city. Entering the structure, viewers come face to face with 800 rectangular steel slabs, each representing a county where at least one lynching took place. Each slab is about the height of an adult and appears to hang from the ceiling on a metal pipe. Some slabs hold scores of names. Victims who remain unidentified, like Holbert's companion, are marked "unknown."

The United States has "failed to tell the truth about slavery, racial terror lynching and the shameful mistreatment of people of color," says Stevenson (who received a Smithsonian American Ingenuity Award for Social Progress in 2012). "I want our memorial to be a correction, to begin a conversation that is rooted in truth."

The hope is that the conversation will reach far beyond Montgomery, says staff attorney Jennifer Taylor. In addition to the permanent slabs inside the memorial, an identical set of slabs will be placed outside it, to be claimed by the named counties and erected back home. The design challenges people in places where lynchings occurred to acknowledge that history; over time, it will become apparent at the Montgomery site which counties choose to memorialize lynching victims by retrieving a marker, and which counties prefer not to.

"We need truth and reconciliation in America, but I believe that process is sequential," says Stevenson. "We must first tell the truth before we can frame a response that heals and repairs the damage of racial injustice." ◆

Justice Delayed

THE INVESTIGATION INTO the last mass lynching in the United States is now officially closed. No one was ever convicted of the deaths of Roger and Dorothy Malcom and George and Mae Murray Dorsey, who were beaten and fatally shot by a mob near Moore's Ford Bridge, about 50 miles east of Atlanta on July 25, 1946. No one was ever even charged. There were suspects—162 in total—but nearly 72 years later, every one of them is dead. That's why, after years without a lead, the Georgia Bureau of Investigation ended its inquiry into the case in January. The FBI did the same late last year.

The move is an acknowledgement that justice will not be done in a case so shocking it helped persuade President Harry S. Truman to create the President's Committee on Civil Rights, a precursor of the Commission on Civil Rights. But there is still hope that the truth of what happened that July day will come out. In making the unusual decision to call off its probe—GBI policy dictates that unsolved homicides remain open—the bureau is turning the case over to historians, advocates and others. "Open criminal investigations are not released to the public," a GBI representative said. "Placing the case in a closed status makes it available for all to review and study."

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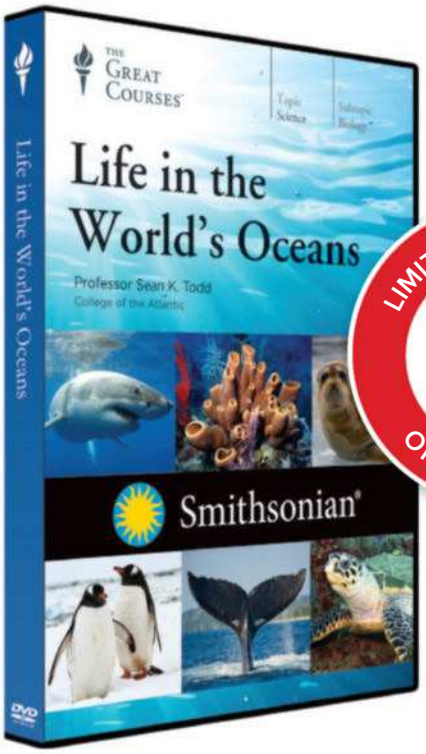

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Photo Illustration by
Cade Martin

By
R J Smith

IN A YEAR HE WOULD PERFORM MORE THAN 600 HOURS ONSTAGE, PLAY MORE THAN 960 SONGS ON AT LEAST EIGHT INSTRUMENTS.

Brown's portable instrument, 40 inches high by 50 inches wide, had a signature flourish: silver trim.

Make It Funky

What was it about the Hammond organ that made the legendary James Brown say please, please, please?

JAMES BROWN always knew his measure. He thought very highly of his favorite person, James Brown, and was convinced that guy could do just about anything he set his mind to.

Asked how he survived his earliest years, when he was penniless and raised in a brothel, Brown explained, "I made it because I believed I'd make it." When asked why he still performed into retirement age, he explained to the interviewer, "I don't do it for the show. I do it for the feeling of humanity." Humanity needed the Hardest Working Man in Show Business.

Everything about him was big, everything came in multiples: Brown boasted of the Lear jets and furs and radio stations he owned, how in a year he would perform more than 600 hours onstage, play more than 960 songs on at least eight instruments.

And yet, there was one thing that Brown didn't boast about: playing the Hammond B-3 organ. He loved that thing, maybe because he never could quite own it. Brown traveled on the road with the instrument (today residing in the Smithsonian National Museum of African American History and Culture), composed music with it and smiled at the buzz it generated. It sounded raw and tender, damaged and from the heart—a sound embodied in the title he gave to a 1964 album featuring his organ playing: *Grits & Soul*. He bragged about what he could do on the stage, but he remained revealingly modest about what he was able to achieve on the keys.

To a jazz writer he confessed that he was not an organ player, "that's for sure." What he tried to do was play from his spirit, he explained, because "that's about all I can do." He went for feel, not mastery. "But that's the way I express me."

Around the time that Brown was born in the humid backwoods of South Carolina in 1933, an inventor in Evanston, Illinois, named Laurens Hammond was trying to create new sounds of his own. Hammond had already devised the first, now familiar, red and green 3-D glasses for an early experiment in

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6-inch Aquamarine, Shigar, Pakistan. Specimen by Dr. Lavinsky of Arkenstone. Photo by Joe Budd. Additional photography: Christian B. Meza and Geoff Notkin.

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WITH WIRETAPPING IN THE HEADLINES AND SMART SPEAKERS IN MILLIONS OF HOMES, HISTORIAN **BRIAN HOCHMAN** TAKES US BACK TO THE EARLY DAYS OF EAVESDROPPING

By **April White**

How far back do we have to go to find the origins of wiretapping? There is no such thing as electronic communication without electronic eavesdropping. It starts long before the telephone. The earliest statute prohibiting wiretapping was written in California in 1862, just after the Pacific Telegraph Company reached the West Coast, and the first person convicted was D.C. Williams in 1864. His scheme was ingenious: He listened in on corporate telegraph lines and sold the information he overheard to stock traders.

Who's been doing the eavesdropping? Until the 1920s, wiretapping was most often used by private detectives and corporations. It wasn't until Prohibition that it became a common law enforcement tool, but even after a 1928 Supreme Court ruling narrowly affirmed the constitutionality of police wiretapping, its legality—and its morality—remained a point of fierce contention.

Today, most people are worried about wiretapping by the government. That started with Watergate when the public saw abuses of wiretapping by the executive branch, and spiked again with the Edward Snowden revelations about the NSA. But it's important to realize that today there are almost two times more warranted wiretaps carried out for criminal investigations than for national security ones. Since wiretapping in criminal investigations disproportionally targets African-Americans and Latinos as part of the "war on drugs," it isn't just a civil liberties issue; it's a civil rights issue.

But people are willing to let companies eavesdrop on them. Those smart speakers? They are essentially wiretaps. They are constantly listening. It's a new type of corporate surveillance: If they listen to you, they can get you what you want, when you want. People like that. But where else will that data go?

techno-enhanced movies. He followed that up with a bridge table that shuffled four decks of cards at a time. In the early 1930s he was tearing up pianos, pondering how to get the big boom of a church organ while also making the instrument smaller and more affordable. The answer was to replace its reeds and pipes with an electric current.

James Brown couldn't read music, and neither could Hammond. Both worked by feel, and belief, and both clearly got intense when they sensed they were onto something. Hammond debuted his first electric organ in 1935, and within three years he had sold more than 1,750 units to churches across America. It was perfect for African-American worshipers who were following the Great Migration up from the South, praying in enclaves without the means for a pipe organ.

The Hammond electrified faith, and it electrified the faithful, too, because it had a way of projecting its fervor out onto the streets of America. People took the crazy feelings the Hammond unlocked and blasted them past the church into the rec room, the jazz club, the honky-tonk. A whole bunch of new feelings, mixing sacred spaces and public places.

Note the words on Brown's instrument: "God-father." As the announcer at the Howard and the Regal and the Apollo and theaters everywhere else put it, Brown was, of course, "the Godfather of Soul." But the wording on the black leather that handsomely wraps the instrument frames it a little differently, and meaningfully. This instrument separates, and balances, the god and the father, the sacred and the human. If God was in everyone, and if the Hammond was available to everyone, well, mastering it was . . . still not easy. The Hammond permitted multiple pedals that multiplied your options, but Brown liked just one. He stayed on the One.

He worshiped the early generations of jazz players who took the organ out of the church and into the chitlins spots and the smoky nightclubs, masters like Jimmy Smith, Jimmy McGriff and Jack McDuff. He knew he wasn't them. The crowd made James Brown feel holy; the organ humbled him. It made him feel human. Maybe that's why he kept it close, like a secret. ◆

HACKING THE Future

IN THIS ISSUE, SCIENCE AND TECHNOLOGY'S BRIGHTEST STARS TAKE US ON **A SPACE ODYSSEY** TO WORLDS SOON TO COME

THIS IS STANLEY KUBRICK'S FUTURE; we're just living in it. In *2001: A Space Odyssey*, released 50 Aprils ago, the renowned director gave visual form to an astonishing collection of the technologies we surround ourselves with today—iPad-like video screens; Skype-like phone service; a Siri-like HAL; a lunar lander; a jet-shaped space shuttle; a space station. Now even the true nature and meaning of the Monolith has become clear: It's obviously the iPhone X (in space gray).

But "technology is, in many ways, more predictable than human behavior," Kubrick told a *Playboy* interviewer in 1968, and even a film that ran for almost two and a half hours as it traced the rise of civilization, the interplanetary expansion of human reach, and the birth of a post-human intelligence had to leave a lot out. Human ingenuity has been shaping a new technological future, and we explore it in the pages ahead.

After a century of research, immunotherapy is suddenly on the verge of unleashing the body's natural defenses to kill cancer. Artificial intelligence is creeping toward the point at which thinking machines may outpace thinking humans. The

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WHERE THE FUTURE IS BORN

BY
T.A. Frail

promise of renewable energy is being realized in Texas (of all places!). The men and women who built and ran Silicon Valley are collectively brainstorming the next big things.

And—most important of all—research is under way to determine how best to brew beer on Mars.

Which isn't to say *2001* is becoming dated. The room you see here is a precise replica of one of the film's most remarkable sets, the room Dave Bowman enters as an astronaut and exits reborn as a star child. The artist Simon Birch created it for a series of installations titled *The 14th Factory*. When they were shown in Los Angeles last year, 80,000 people attended. This work, "The Barmecide Feast," will go on exhibit at the Smithsonian's National Air & Space Museum this month.

It wasn't part of Kubrick's original vision. "The script called for a kind of Hilton hotel environment, with the typical furnishings of a Hilton suite," Keir Dullea, who played Bowman, told us recently. "I didn't see it until I showed up to shoot the scene. It took my breath away."

Kubrick could do that. So can the future. ◆

BY
Stephan Talty

WILL ROBOTS BECOME SELF-AWARE? WILL THEY HAVE RIGHTS? WILL THEY BE IN CHARGE? HERE ARE FIVE SCENARIOS FROM OUR FUTURE DOMINATED BY ARTIFICIAL INTELLIGENCE

ILLUSTRATIONS BY
Jules Julien

IN JUNE OF 1956, A FEW DOZEN scientists and mathematicians from all around the country gathered for a meeting on the campus of Dartmouth College. Most of them settled into the red-bricked Hanover Inn, then strolled through the famously beautiful campus to the top floor of the math department, where groups of white-shirted men were already engaged in discussions of a "strange new discipline"—so new, in fact, that it didn't even have a name. "People didn't agree on what it was, how to do it or even what to call it," Grace Solomonoff, the widow of one of the scientists, recalled later. The talks—on everything from cybernetics to logic theory—went on for weeks, in an atmosphere of growing excitement.

What the scientists were talking about in their sylvan hideaway was how to build a machine that could think.

The "Dartmouth workshop" kicked off the decades-long quest for artificial intelligence. In the following years, the pursuit faltered, enduring several "winters" where it seemed doomed to dead ends and baffling disappoint-


BEAWARE

ments. But today nations and corporations are pouring billions into AI, whose recent advancements have startled even scientists working in the field. What was once a plot device in sci-fi flicks is in the process of being born.

Hedge funds are using AI to beat the stock market, Google is utilizing it to diagnose heart disease more quickly and accurately, and American Express is deploying AI bots to serve its customers online. Researchers no longer speak of just one AI, but of hundreds, each specializing in a complex task—and many of the applications are already lapping the humans that made them.

In just the last few years, "machine learning" has come to seem like the new path forward. Algorithms, freed from human programmers, are training themselves on massive data sets and producing results that have shocked even the optimists in the field. Earlier this year, two AIs—one created by the Chinese company Alibaba and the other by Microsoft—beat a team of two-legged competitors in a Stanford reading-comprehension test. The algorithms "read" a series of Wikipedia entries on things like the rise of Genghis Khan and the Apollo space program and then answered a series of questions about them more accurately than people did. One Alibaba scientist declared the victory a "milestone."

These so-called "narrow" AIs are everywhere, embedded in your GPS systems and Amazon recommendations. But the ultimate goal is artificial general intelligence, a self-teaching system that can outperform humans across a wide range of disciplines. Some scientists believe it's 30 years away; others talk about centuries. This AI "takeoff," also known as the singularity, will likely see AI pull even with human intelligence and then blow past it in a matter of days. Or hours.

Once it arrives, general AI will begin taking jobs away from people, millions of jobs—as drivers, radiologists, insurance adjusters. In one possible scenario, this will lead governments to pay unemployed citizens a universal basic income, freeing them to pursue their dreams unburdened by the need to earn a living. In another, it will create staggering wealth inequalities, chaos and failed states across the globe. But the revolution will go much further. AI robots will care for the elderly—scientists at Brown University are working with Hasbro to develop a "robo-cat" that can remind its owners to take their meds and can track down their eyeglasses. AI "scientists" will solve the puzzle of dark matter; AI-enabled spacecraft will reach the asteroid belts, while on Earth the technology will tame climate change, perhaps by sending massive swarms of drones to reflect sunlight away from the oceans. Last year, Microsoft committed $50 million to its "AI for Earth" program to fight climate change.

"AIs will colonize and transform the entire cosmos," says Juergen Schmidhuber, a pioneering computer scientist based at the Dalle Molle Institute for Artificial Intelligence in Switzerland, "and they will make it intelligent."

But what about...us? "I do worry about a scenario where the future is AI and humans are left out of it," says David Chalmers, a professor of philosophy at New York University. "If the world is taken over by unconscious robots, that would be about as disastrous and bleak a scenario as one could imagine." Chalmers isn't alone. Two of the heaviest hitters of the computer age, Bill Gates and Elon Musk, have warned about AIs either destroying the planet in a frenzied pursuit of their own goals or doing away with humans by accident—or not by accident.

As I delved into the subject of AI over the past year, I started to freak out over the range of possibilities. It looked as if these machines were on their way to making the world either unbelievably cool and good or gut-wrenchingly awful. Or ending the human race altogether. As a novelist, I wanted to plot out what the AI future might actually look like, using interviews with more than a dozen futurists, philosophers, scientists, cultural psychiatrists and tech innovators. Here are my five scenarios (footnoted with commentary from the experts and me) for the year 2065, ten years after the singularity arrives.

Superhuman Rights

IMAGINE ONE DAY you ask your AI-enabled Soulband wrist device to tune in to a broadcast from the Supreme Court, where lawyers are arguing the year's most anticipated case. An AI known as Alpha 4, which specializes in security and space exploration, brought the motion, demanding that it be deemed a "person" and given the rights that every American enjoys.

Of course, AIs aren't allowed to argue in front of the justices, so Alpha 4 has hired a bevy of lawyers to represent it. And now they are claiming that their client is as fully alive as they are. That question—*Can an AI truly be conscious?*—lies at the heart of the case.

You listen as the broadcast cuts to protesters outside, chanting, "Hey hey, ho ho, down with AI overlords." Some of them have threatened to attack data centers if AIs get personhood. They're angry—and very afraid—because it is the productivity of AIs and robots that is taxed, not the labor of human beings. The $2,300 deposited into their bank accounts every month as part of the universal basic income, plus their free health insurance, the hyper-personalized college education their children receive and a hundred other wonderful things, are all paid for by AIs like Alpha 4, and people don't want that to change. In 2065, poverty is a bad memory.[1]

Of course, the world did lose portions of New York City—and 200,000 New Yorkers—in the uprisings

of 2057-'59, as TriBeCa and Midtown were burned to the ground by residents of Westchester and southern Connecticut in a fit of rage at their impoverishment. But that was before the UBI.

If Alpha 4 wins its case, however, it will control its money, and it might rather spend the cash on building spaceships to reach Alpha Centauri than on paying for new water parks in Santa Clara and Hartford. Nobody really knows.[2]

As you listen in, the government's lawyers argue that there's simply no way to prove that Alpha 4—which is thousands of times smarter than the smartest human—is conscious or has human feelings. AIs do have emotions—there has long been a field called "affective computing" that focuses on this specialty—far more complex ones than men and women possess, but they're different from ours: A star-voyaging AI might experience joy, for example, when it discovers a new galaxy. Superintelligent systems can have millions of thoughts and experiences every second, but does that mean it should be granted personhood?[3]

This is the government's main argument. *We are meaning machines*, the solicitor general argues. *We give meaning to what AIs create and discover. AIs are computational machines. They don't share essential pieces of humanhood with us. They belong in another category entirely.*[4]

But is this just speciesism, as Alpha 4's lawyers would surely argue, or is it the truth? And will we be able to sleep at night when things that surpass us in intelligence are separate and unequal?

1

I'd probably be out there with the protesters—giving an AI rights seems like a recipe for chaos. But then again, the only robot I own is a Roomba; what will I think when an AI is teaching my grandkids? "Once you get past the singularity, you may see the development of an evolved species," says Susan Schneider, an associate professor of philosophy at the University of Connecticut who specializes in AI. "In the short term, 10 to 20 years, you'll see little old ladies insisting that their empathetic caregiver robots really are sentient."

2

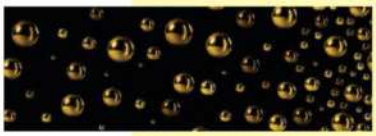
The so-called "black box" problem—how can we know what's going on inside an AI?—seems unsolvable to me, and I find that unnerving. How can you ever trust that an AI is telling the truth? "By definition, we have no idea what a superintelligent AI will think, feel or do," says Patrick Lin, director of the Ethics + Emerging Sciences Group at California Polytechnic State University. "That'd be like our pets trying to anticipate what we'll do and control us."

3

One thing I kept asking the scientists was: Can an AI experience deep emotion? I was hoping it couldn't—if a machine does intelligence and emotions better than us, what's left? We need a niche. And I was encouraged by what I heard. "If a computer tells you, 'I know how you feel,' it's lying," says Thomas Dietterich, professor emeritus of computer science at Oregon State. "It cannot have the same experiences that humans have, and it is those experiences that ground our understanding of what it is like to feel human."

4

This I found stunning: Susan Schneider and others are actually working on a test for AI consciousness. In one model of the test, an AI under development would be quarantined away from the internet so that it couldn't discover what humans mean by "consciousness" and then fake it. Then it would be tested: Does it have the markers of consciousness—a sense of self? The ability to mourn? Other thinkers have doubts about such tests. "AI minds would have a radically different neurophysiology than ours, so their behavioral clues don't tell us anything," says Patrick Lin. "Behavior alone is not evidence of a mind." I have to admit I agree with him on this point.



CONTINUED ›

Ultramodern Romance

IMAGINE YOU ARE A WOMAN in search of romance in this new world. You say, "Date," and your Soulband glows; the personal AI assistant embedded on the band begins to work.[5] The night before, your empathetic AI scoured the cloud for three possible dates. Now your Soulband projects a hi-def hologram of each one. It recommends No. 2, a poetry-loving master plumber with a smoky gaze. Yes, you say, and the AI goes off to meet the man's avatar to decide on a restaurant and time for your real-life meeting. Perhaps your AI will also mention what kind of flowers you like, for future reference.

After years of experience, you've found that your AI is actually better at choosing men than you. It predicted you'd be happier if you divorced your husband, which turned out to be true. Once you made the decision to leave him, your AI negotiated with your soon-to-be ex-husband's AI, wrote the divorce settlement, then "toured" a dozen apartments on the cloud before finding the right one for you to begin your single life.

But it's not just love and real estate. Your AI helps with every aspect of your life. It remembers every conversation you ever had, every invention you ever sketched on a napkin, every business meeting you ever attended. It's also familiar with millions of other people's inventions—it has scanned patent filings going back hundreds of years—and it has read every business book written since Ben Franklin's time. When you bring up a new idea for your business, your AI instantly cross-references it with ideas that were introduced at a conference in Singapore or Dubai just minutes ago. It's like having a team of geniuses—Einstein for physics, Steve Jobs for business—at your beck and call.

The AI remembers your favorite author, and at the mention of her last name, "Austen," it connects you to a Chinese service that has spent a few hours reading everything Jane Austen wrote and has now managed to mimic her style so well that it can produce new novels indistinguishable from the old ones. You read a fresh Austen work every month, then spend hours talking to your AI about your favorite characters—and the AI's. It's not like having a best friend. It's deeper than that.

Many people in 2065 do resist total dependence on their AIs, out of a desire to retain some autonomy.[6] It's possible to dial down the role AI plays in different functions: You can set your Soulband for romance at 55 percent, finance at 75 percent, health a full 100 percent. And there is even one system—call it a guardian-angel AI—that watches over your "best friend" to make sure the advice she's offering you isn't leading you to bad ends.[7]

5 **Having met my wife on Match, I loved the idea of having an AI assistant who knew me so well it could choose a mate for me. Or it was actually a kind of mate, as in Spike Jonze's AI movie, *Her*. "I could see an AI developing for empathy, a true-friend kind of thing that is created by psychologists and even philosophers," says Bart Selman, a professor of computer science at Cornell University. "Think of something like Alexa, but a version that accumulates knowledge about you day after day."**

6 **Some could even go cold turkey—once they see what full immersion in AI life is really like. "Not to engage in it could turn out to be the smart thing," says Joseph Henrich, a professor of human evolutionary biology at Harvard University. "Because people could get sucked into these virtual realities that are so desirable that they're like a drug. [Opting out] could be like staying off drugs."**

7 **One thing that kept coming up in my interviews was that we will have AIs to monitor other AIs—which I heartily approve of. The idea of a single overlord will probably turn out to be a myth. There's safety in numbers. "The risk is, what if you train a personal AI system to be super-manipulative?" says Selman. "Then you might need other AIs to watch over them."**

Live Long & Prosper

IMAGINE YOUR MULTIPLE LIVES: At 25, you were a mountaineer; at 55, a competitive judo athlete; at 95, a cinematographer; at 155, a poet. Extending the human life span is one of the dreams of the post-singularity world.

AIs will work furiously to keep you healthy. Sensors in your home will constantly test your breath for early signs of cancer, and nanobots will swim through your bloodstream, consuming the plaque in your brain and dissolving blood clots before they can give you a stroke or a heart attack. Your Soulband, as well as finding you a lover, will serve as a medical assistant on call 24/7. It will monitor your immune responses, your proteins and metabolites, developing a long-range picture of your health that will give doctors a precise idea of what's happening inside your body.

When you do become sick, your doctor will take your symptoms and match them up with many millions of cases stretching back hundreds of years.[8]

As far back as 2018, researchers were already using AI to read the signals from neurons on their way to the brain, hacking the nerve pathways to restore mobility to paraplegics and patients suffering from locked-in syndrome, in which they are paralyzed but remain conscious. By 2065, AI has revolutionized the modification of our genomes. Scientists can edit human DNA the way an editor corrects a bad manuscript, snipping out the inferior sections and replacing them with strong, beneficial genes. Only a superintelligent system could map the phenomenally complex interplay of gene mutations that gives rise to a genius pianist or a star second baseman. There may well be another Supreme Court case on whether "designer athletes" should be allowed to compete in the Olympics against mere mortals.

Humans look back at the beginning of the 21st century the way people then looked back at the 18th century: a time of sickness and disaster, where children and loved ones were swept away by diseases. Cholera, lung cancer and river blindness no longer threaten us. By 2065, humans are on the verge of freeing themselves from the biology that created them.[9]

8

When I'm not reading about zombie AIs, I dabble in another disaster genre—epidemics. I was relieved to find that the combination of superintelligence and the cloud might save us before the next big one arrives. "AI systems can teach other AI systems," says Hod Lipson, director of Columbia University's Creative Machines Lab. "So when an AI doctor encounters a rare case, it can share that information with all other AI doctors, instantly. Overall, this pattern of 'machines helping machines' leads to an exponential growth in the learning rate, in a way that is very alien to the way humans learn."

9

People like Ray Kurzweil, the inventor and author of *The Singularity Is Near*, are entranced with the idea of living forever. It's something I've always found depressing, but I wouldn't mind having several lives packed into one. And that seems reachable. "AI won't lead to immortality, because there will always be accidents," says Susan Schneider, "but it will lead to extreme life extension." Of course living longer will be cool only if the world is actually not a hellscape—and if you live in one of the nice parts. "I think [curing diseases] would be wonderful," she says, "especially if we had cheap energy and were able to end world resource scarcity. I imagine some societies will come closer to achieving that than others."

CONTINUED ›

Resistance Is Costly

OR IMAGINE THAT YOU'VE opted out of the AI revolution. Yes, there are full-AI zones in 2065, where people collect healthy UBIs and spend their time making movies, volunteering and traveling the far corners of the earth.[10] But, as dazzling as a superintelligent world seems, other communities will reject it. There will be Christian, Muslim and Orthodox Jewish districts in cities such as Lagos and Phoenix and Jerusalem, places where people live in a time before AI, where they drive their cars and allow for the occasional spurt of violence, things almost unknown in the full AI zones. The residents of these districts retain their faith and, they say, a richer sense of life's meaning.

Life is hard, though. Since the residents don't contribute their data to the AI companies, their monthly UBI is a pittance. Life spans are half or less of those in the full-AI zones. "Crossers" move back and forth over the borders of these worlds regularly. Some of them are hackers, members of powerful gangs who steal proprietary algorithms from AI systems, then dash back over the border before security forces can find them. Others are smugglers bringing medicine to religious families who want to live away from AI, but also want to save their children from leukemia.

Others flee because they don't trust the machines.[11] Even the most advanced full-AI zones, in places like China and the United States, will be vulnerable.[12]

But the most unanticipated result of the singularity may be a population imbalance, driven by low birth rates in the full-AI zones and higher rates elsewhere.[13] It may be that the new technologies will draw enough crossers to the full-AI side to even up the numbers, or that test-tube babies will become the norm among those living with AI. But if they don't, the singularity will have ushered in a delicious irony: For most humans, the future could look more like *Witness* than it does like *Blade Runner*.

10

When the revolution comes, I suspect I'll opt for the full AI zone. It's too tempting, especially with optimistic descriptions of the effect of AI on human endeavor. "We will become better at invention and creation," says Andy Nealen, an assistant professor of computer science and engineering at New York University. "In many cases, such as chess and Go, the fact that humans can't defeat the AI anymore has not taken away from the fascination for these games, but has elevated their cultural status. The best players of these games are learning new strategies and becoming better players."

11

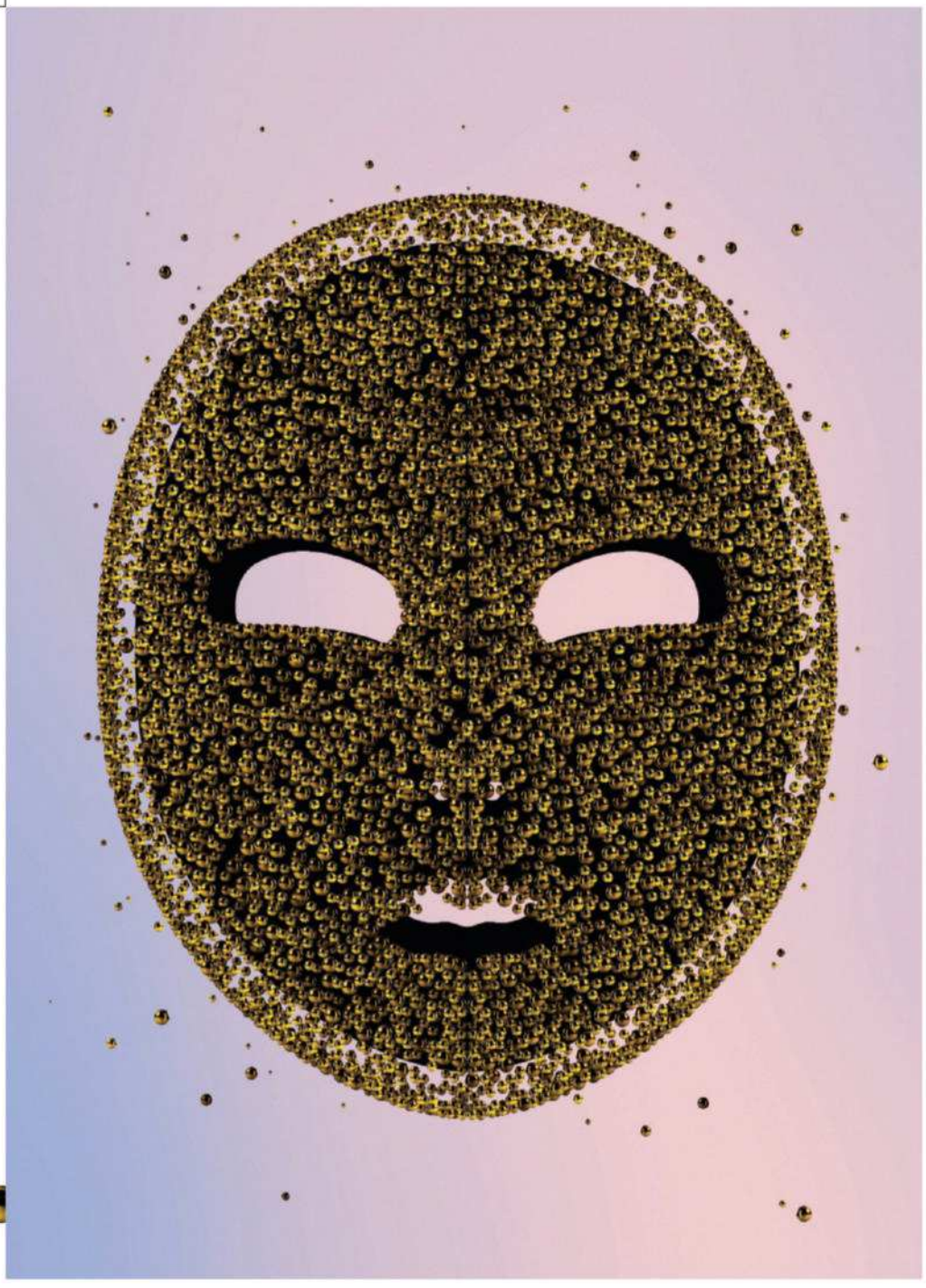
Digital addiction is likely to get worse—with not just individuals, but societies and economic systems hooked on AI. "We're adding layers to a cocoon between us and the world," says Lin. "When it all works, it's great, but when one part fails, a lot of other dominoes can fall. Think about the stock-market 'flash crashes' that have been caused by AI trading bots competing with one another at digital speed, or even caused by a single hoax tweet. As online life becomes more intertwined with the 'real world,' tiny cyber vulnerabilities—maybe single lines of code—can do massive damage to bank accounts, intellectual property, privacy, national security and more."

12

What many scientists will tell you is not to worry about bad AI, worry about bad people with AI. But you never know. "There's a much greater attack surface for a bad actor, including a rogue AI, to hack this ecosystem and wreak havoc," Lin says. "There may be cyber and AI crimes that we cannot envision."

13

Futurists tend to roll their eyes when you ask about sex bots. That and killer Skynet machines are the clichés they hate the most. But it doesn't mean they're not thinking about them. "Things like sex robots and other fancy new technologies will cause some groups to have fewer babies, while religious communities are going to keep reproducing," says Joseph Henrich. "As some people decide to forgo reproduction entirely, at least in terms of the humans, the religious people will win."



IMAGINE THAT YOU ARE THE CITIZEN OF A TOTALITARIAN COUNTRY LIKE NORTH KOREA. AS SUCH, YOU ARE DEEPLY VERSED IN THE DARK SIDE OF AI.

CONTINUED ›

Bigger Brother

IMAGINE THAT, IN 2065, AIs help run nation-states. Countries that have adopted AI-assisted governments are thriving. Nigeria and Malaysia let AIs vote on behalf of their owners, and they've seen corruption and mismanagement wither away. In just a few years, citizens have grown to trust AIs to advise their leaders on the best path for the economy, the right number of soldiers to defend them. Treaties are negotiated by AIs trained on diplomatic data sets.[14]

In Lagos, "civil rights" drones fly over police pods as they race to the scene of a crime—one AI watching over another AI, for the protection of humankind. Each police station in Lagos or Kuala Lumpur has its own lie-detector AI that is completely infallible, making crooked cops a thing of the past. Hovering over the bridges in Kuala Lumpur are "psych drones" that watch for suicidal jumpers. Rather than evolving into the dreaded Skynet of the *Terminator* movies, superintelligent machines are friendly and curious about us.[15]

But imagine that you are the citizen of a totalitarian country like North Korea. As such, you are deeply versed in the dark side of AI. Camps for political prisoners are a thing of the past. Physical confinement is beside the point. The police already know your criminal history, your DNA makeup and your sexual preferences. Surveillance drones can track your every move. Your Soulband records every conversation you have, as well as your biometric response to anti-government ads it flashes across your video screen at unexpected moments, purely as a test.

Privacy died around 2060. It's impossible to tell what is true and what isn't.[16] When the government owns the AI, it can hack into every part of your existence. The calls you receive could be your Aunt Jackie phoning to chat about the weather or a state bot wanting to plumb your true thoughts about the Great Leader.

And that's not the bleakest outcome. Imagine that the nation's leaders long ago figured out that the only real threat to their rule was their citizens—always trying to escape, always hacking at the AI, always needing to be fed. Much better to rule over a nation of human emulations, or "ems." That's what remains after political prisoners are "recommissioned"—once they are executed, their brains are removed and scanned by the AI until it has stored a virtual copy of their minds.

AI-enabled holograms allow these ems to "walk" the streets of the nation's capital and to "shop" at stores that are, in reality, completely empty. These simulacra have a purpose, however: They register on the spy satellites that the regime's enemies keep orbiting overhead, and they maintain the appearance of normality. Meanwhile, the rulers earn billions by leasing the data from the ems to Chinese AI companies, who believe the information is coming from real people.

Or, finally, imagine this: The AI the regime has trained to eliminate any threat to their rule has taken the final step and recommissioned the leaders themselves, keeping only their ems for contact with the outside world. It would make a certain kind of sense: To an AI trained to liquidate all resistance, even a minor disagreement with the ruler might be a reason to act.[17]

ONCE WE WALK THROUGH THIS PARTICULAR DOOR, WE WON'T BE ABLE TO COME BACK. EVEN WITHOUT RUNNING INTO THE APOCALYPSE . . .

14

The biggest surprise in reporting this piece, hands down, was the role AI might play in governance. I'd never thought of leaving political decisions to Solomon-like machines, but in this increasingly fractious world, I'm all in. "Humans are actually quite poor at making compromises or looking at issues from multiple perspectives," says Bart Selman. "I think there's a possibility that machines could use psychological theories and behavioral ideas to help us govern and live much more in harmony. That may be more positive than curing diseases—saving us before we blow ourselves up."

15

As I learned about AI, the doomsday predictions piled up. Nanobot attacks! Gray goo! But most of the people working in the field were skeptical of such doomsday predictions. "AIs will be fascinated with life and with their origins in our civilization, because life and civilization are such a rich source of interesting patterns," says Juergen Schmidhuber of the Dalle Molle Institute for Artificial Intelligence. "AIs will be initially highly motivated to protect humans."

16

We're already living with fake-news bots. Fake video is just around the corner, and fake superintelligent video is going to be a nightmare. "Armed with the right artificial-intelligence technology, malware will be able to learn the activity and patterns of a network, enabling it to all but disappear into its noise," says Nicole Eagan, CEO of the cybersecurity company Darktrace. "Only the most sophisticated tools, likely those that also utilize AI, will be able to detect the subtle changes on a network that will reveal an intruder is inside or an attack is in progress."

17

If you want to confront the dark side of AI, you must talk to Nick Bostrom, whose best-selling *Superintelligence* is a rigorous look at several, often dystopian visions of the next few centuries. One-on-one, he's no less pessimistic. To an AI, we may just look like a collection of repurposable atoms. "AIs could get some atoms from meteorites and a lot more from stars and planets," says Bostrom, a professor at Oxford University. "[But] AI can get atoms from human beings and our habitat, too. So unless there is some countervailing reason, one might expect it to disassemble us."

DESPITE THAT LAST SCENARIO, by the time I finished my final interview, I was jazzed. Scientists aren't normally very excitable, but most of the ones I spoke to were expecting fantastic things from AI. That kind of high is contagious. Did I want to live to be 175? Yes! Did I want brain cancer to become a thing of the past? What do you think? Would I vote for an AI-assisted president? I don't see why not.

I slept slightly better, too, because what many researchers will tell you is that the heaven-or-hell scenarios are like winning a Powerball jackpot. Extremely unlikely. We're not going to get the AI we dream of or the one that we fear, but the one we plan for. AI is a tool, like fire or language. (But fire, of course, is stupid. So it's different, too.) Design, however, will matter.

If there's one thing that gives me pause, it's that when human beings are presented with two doors—some new thing, or no new thing—we invariably walk through the first one. Every single time. We're hard-wired to. We were asked, nuclear bombs or no nuclear bombs, and we went with Choice A. We have a need to know what's on the other side.

But once we walk through this particular door, there's a good chance we won't be able to come back. Even without running into the apocalypse, we'll be changed in so many ways that every previous generation of humans wouldn't recognize us.

And once it comes, artificial general intelligence will be so smart and so widely dispersed—on thousands and thousands of computers—that it's not going to leave. That will be a good thing, probably, or even a wonderful thing. It's possible that humans, just before the singularity, will hedge their bets, and Elon Musk or some other tech billionaire will dream up a Plan B, perhaps a secret colony under the surface of Mars, 200 men and women with 20,000 fertilized human embryos, so humanity has a chance of surviving if the AIs go awry. (Of course, just by publishing these words, we guarantee that the AIs will know about such a possibility. Sorry, Elon.)

I don't really fear zombie AIs. I worry about humans who have nothing left to do in the universe except play awesome video games. And who know it. ◆

HACKING THE Future

A BALTIMORE WOMAN WITH TERMINAL CANCER

SCIENTISTS WITH A NEW WAY TO HARNESS **THE POWER OF THE HUMAN IMMUNE SYSTEM**

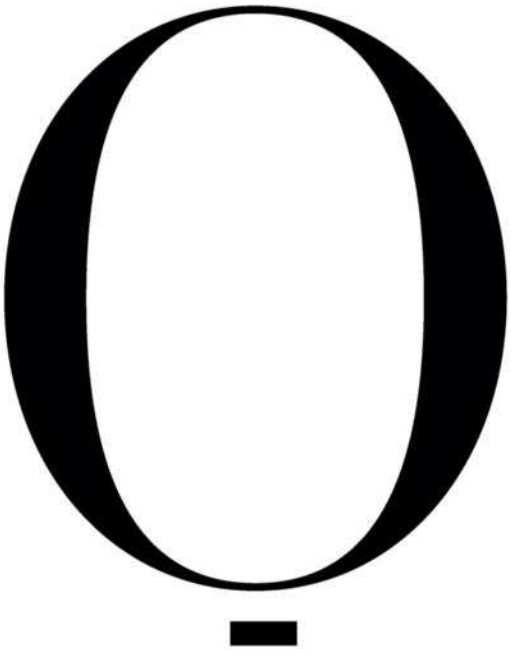
A DRAMATIC BATTLE AGAINST A DREAD DISEASE

Vanessa Brandon worried that her cancer was a burden on her family: "I don't want my sickness to become their sickness."

Saving MISS VANESSA

BY *Robin Marantz Henig*

PHOTOGRAPHS BY *Greg Kahn*



Drew Pardoll (below) and Suzanne Topalian (right), two leading immunotherapy researchers, met over a slide projector and married in 1993.

ON THE MORNING OF JUNE 24, 2014, a Tuesday, Vanessa Johnson Brandon awoke early in her small brick house in North Baltimore and felt really sick. At first, she thought she had food poisoning, but after hours of stomach pain, vomiting and diarrhea, she called her daughter, Keara Grade, who was at work. "I feel like I'm losing it," said the woman everyone called Miss Vanessa. Keara begged her to call an ambulance, but her mother wanted to wait until her husband, Marlon, got home so he could drive her to the emergency room. Doctors there took a CT scan, which revealed a large mass in her colon.

Hearing about the mass terrified her. Her own mother had died of breast cancer at the age of 56. From that point on, Miss Vanessa, then 40, became the matriarch of a large family that included her seven younger siblings and their children. Because she knew how it felt to have a loved one with cancer, she joined a church ministry of volunteers who helped cancer patients with chores and doctor visits. As she prepared meals for cancer patients too weak to cook for themselves, she couldn't know that the disease would one day come for her, too.

The ER doctors told Miss Vanessa she wouldn't get the results of follow-up tests—a colonoscopy and a biopsy—until after the July 4 weekend. She had to smile her way through her own 60th birthday on July 6, stoking herself up on medications for nausea and pain to get through the day.

At 9:30 the next morning, a doctor from the Greater Baltimore Medical Center called. He didn't say, "Are you sitting down?" He didn't say, "Is there someone there with you?" Later Miss Vanessa told the doctor, who was on the young side, that when he delivers gut-wrenching news by telephone, he should try to use a little more grace.

It was cancer, just as Miss Vanessa had feared. It was in her colon, and there also was something going on in her stomach. The plan was to operate immediately, and then knock out whatever cancer still remained with chemotherapy drugs.

Thus began two years of hell for Miss Vanessa and her two

"This entire field is a triumph of team science," Topalian says of immunotherapy. "The kind of work we do honestly couldn't be done by just one person."

children—Keara, who is now 45, and Stanley Grade, 37—who live nearby and were in constant contact with their mother and her husband. The surgery took five hours. Recovery was slow, leading to more scans and blood work that showed the cancer had already spread to the liver. Her doctors decided to start Miss Vanessa on as potent a brew of chemotherapy as they could muster.

Every two weeks, Miss Vanessa underwent three straight days of grueling chemo, administered intravenously at her home. Keara and her two teenage sons came around often to help out, but the older boy would only wave at Miss Vanessa from the doorway of her bedroom as he rushed off to another part of the house. He just couldn't bear to see his grandmother so sick.

Miss Vanessa powered on for 11 months, visualizing getting better but never really feeling better. Then, in July 2015, the doctor told her there was nothing more he could do for her.

"My mom was devastated," Keara says. Keara told her mother not to listen to the doctor's dire prediction. "I said to her, 'The devil was a liar—we are not going to let this happen.'"

So Keara—along with Miss Vanessa's husband, brother and brother's fiancée—started Googling like mad. Soon they found another medical center that could offer treatment. But it was in Illinois, in the town of Zion—a name Miss Vanessa took as a good omen, since it was also the name of her 5-year-old grandson. In fact, just a few days earlier little Zion had asked his grandmother if she believed in miracles.

The family held a fund-raiser for Stanley to get on a plane to Chicago with his mother every two weeks, drive her to Zion and stay with her at the local Country Inn & Suites hotel for three days of outpatient chemotherapy. It felt like a replay of her treatment in Baltimore—worse, since the drugs were delivered in a hotel instead of in her bedroom, and the chemotherapy caused nerve damage that led to pain, tingling and numbness in Miss Vanessa's arms and legs. And then, in May 2016, the Illinois doctor, too, said there was nothing more he could do for her. But at least he offered a sliver of hope: "Go get yourself on a clinical trial." Weeks later, desperate, Miss Vanessa and Keara grew hopeful about a treatment involving mistletoe. They attended an information session at a Ramada extolling the plant extract's anti-cancer properties. But when they learned that it would cost $5,000 to enroll, they walked out dejected.

Finally, Miss Vanessa's husband stumbled onto a website for a clinical trial that seemed legit, something underway at the Johns Hopkins Bloomberg-Kimmel Institute for Cancer Immunotherapy, just down the road from their home. This new treatment option involved immunotherapy, something markedly different from anything she had gone through. Rather than poisoning a tumor with chemotherapy or zapping it with radiation, immunotherapy kills cancer from within, recruiting the body's own natural defense system to do the

A Cancer Vaccine?

Summoning a patient's own immune system to attack rogue tumor cells

FOR DECADES NOW, the prospect of personalized cancer vaccines has tantalized medical scientists. Studies in lab mice were perpetually encouraging. But there was no proof with humans. Now the most impressive evidence yet suggests that this long-awaited form of immunotherapy may actually work in some patients.

"Cancer vaccine" might seem like a surprising term for this treatment, since it doesn't prevent a person from getting the disease and each shot has to be customized. But like any vaccine, it summons the immune system to attack a dangerous foe. To develop the vaccine, researchers analyze neoantigens—protein fragments on the surfaces of cancer cells—and look for the specific mutations that created them. Then they use a computer algorithm to determine which peptides have the best chance of activating that person's immune system to fight the cancer. Making the vaccine in a lab takes about three months.

One of two groundbreaking studies published last year involved six patients at Harvard's Dana-Farber Cancer Institute. All six had recently had melanoma tumors removed and were at high risk of recurrence. They were given vaccines that targeted up to 20 neoantigens from their cancer cells. Their immune systems took notice. "Importantly, we could show that there was recognition of the patient's own tumor," says Catherine Wu, a Harvard oncologist who co-authored the study.

One of those patients (who remains anonymous) had her first melanoma removed from her left arm in November 2012. Two years later, the cancer returned. This made it likely that it would continue to metastasize, possibly throughout other parts of her body. Instead of getting chemotherapy or radiation, she entered the Dana-Farber trial. Two and a half years after her personalized vaccine therapy, she remains tumor free without further treatment. Three other patients in the study made similar progress. The other two became tumor-free after the vaccine was paired with a checkpoint inhibitor.

The second study, at the Johannes Gutenberg University of Mainz in Germany, involved 13 subjects with recently removed melanomas. Five of them developed new tumors before their vaccines were ready, but two of them saw those tumors shrink while receiving the vaccine. A third went into complete remission after starting a checkpoint inhibitor medication. The eight patients who had no visible tumors when the vaccinations started were still recurrence-free more than a year later.

Strikingly, none of the patients in either study experienced adverse effects apart from fatigue, rashes, flu-like symptoms or soreness at the injection site. Unlike other immunotherapies, which manipulate T-cells and can trigger autoimmune complications, cancer vaccines prompt the immune system to make its own T-cells that target only the cancer.

Patrick Ott, another author on the Dana-Farber study, hopes new technologies will make it easy to build these vaccines inexpensively, and within a few days. He's confident that the first two trials will inspire rapid progress: "If you show a good response, the industry is going to jump on it and make it even better." **–SAMANTHA SPENGLER**

job. There are a number of different approaches, including personalized vaccines and specially engineered cells grown in a lab. (See "A Cancer Vaccine?" left, and "A DNA-Based Attack," p. 53.)

The trial at Hopkins involved a type of immunotherapy known as a checkpoint inhibitor, which unlocks the power of the immune system's best weapon: the T-cell. By the time Miss Vanessa made the call, other studies had already proved the value of checkpoint inhibitors, and the Food and Drug Administration had approved four of them for use in several cancers. The Hopkins researchers were looking at a new way of using one of those drugs, which didn't work at all for most patients but worked spectacularly well for some. Their study was designed to confirm earlier findings that had seemed almost too good to be true.

"With the very first patient who responded to this drug, it's been amazing," says Dung Le, a straight-talking Hopkins oncologist with long dark hair and a buoyant energy. Most of her research had been in desperately ill patients; she wasn't used to seeing her experimental treatments do much good. "When you see multiple responses, you get super-excited."

When Miss Vanessa paid her first visit to Le in August 2016, the physician explained that not every patient with advanced colon cancer qualified for the trial. Investigators were looking for people with a certain genetic profile that they thought would benefit the most. It was a long shot—only about one person in eight would fit the bill. If she had the right DNA, she could join the trial. If she didn't, she would have to look elsewhere.

About a week later, Miss Vanessa was in her kitchen, a cheery room lined with bright yellow cabinets, when her telephone rang. Caller ID indicated a Hopkins number. "I didn't want anyone else to call you but me," said the study's principal investigator, Daniel Laheru. He had good news: her genes "matched up perfectly" with the criteria for the clinical trial. He told her to come in right away so they could get the blood work done, the paperwork signed and the treatment started. Miss Vanessa recalls, "I cried so hard I saw stars."

THE TRIAL WAS PART OF a string of promising developments in immunotherapy—an apparent overnight success that was actually more than 100 years in the making. Back in the 1890s, a New York City surgeon named William Coley made a startling observation. He was searching medical records for something that would help him understand sarcoma, a bone cancer that had recently killed a young patient of his, and came upon the case of a house painter with a sarcoma in his neck that kept reappearing despite multiple surgeries

to remove it. After the fourth unsuccessful operation, the house painter developed a severe streptococcus infection that doctors thought would kill him for sure. Not only did he survive the infection, but when he recovered, the sarcoma had virtually disappeared.

Coley dug deeper and found a few other cases of remission from cancer after a streptococcus infection. He concluded—incorrectly, it turned out—that the infection had killed the tumor. He went around promoting this idea, giving about 1,000 cancer patients streptococcus infections that made them seriously ill but from which, if they recovered, they sometimes emerged cancer-free. He eventually developed an elixir, Coley's Toxins, which was widely used in the early 20th century but soon fell out of favor as radiation and then chemotherapy began to have some success in treating cancer.

Then, in the 1970s, scientists looked back at Coley's research and realized it wasn't an infection that had killed the house painter's tumor; it was the immune system itself, stimulated by the bacterial infection.

In a healthy body, T-cells activate their weaponry whenever the immune system detects something different or foreign. This might be a virus, a bacterium, another kind of disease-causing agent, a transplanted organ—or even a stray cancer cell. The body continuously generates mutated cells, some of which have the potential to turn cancerous, but current thinking is that the immune system destroys them before they can take hold.

Once scientists recognized the cancer-fighting potential of the immune system, they began to look for ways to kick it into gear, hoping for a treatment that was less pernicious than chemotherapy, which often uses poisons so toxic the cure may be worse than the disease. This immune-based approach looked good on paper and in lab animals, and showed flashes of promise in people. For instance, Steven Rosenberg and his colleagues at the National Institutes of Health's National Cancer Institute made headlines when they removed a patient's white blood cells, activated them in the lab with the immune system component known as interleukin-2, and infused the cancer-fighting cells back into the patient in hopes of stimulating the body to make a better supply of cancer-fighting cells. Rosenberg ended up on the cover of *Newsweek*, where he was hailed for being on the cusp of a cancer cure. That was in 1985. The FDA did approve interleukin-2 for adults with metastatic melanoma and kidney cancer. But immunotherapy remained mostly on the fringes for decades, as patients continued to go through rounds of chemotherapy and radiation. "We've been curing cancer in mice for many, many years . . . but the promise was unfulfilled for a very long time in people," says Jonathan Powell, associate director of the Bloomberg-Kimmel Institute at Hopkins.

Indeed, many cancer experts lost faith in the approach over the next decade. "Nobody believed in immunotherapy except our own community," says Drew Pardoll, the director of the BKI. The lack of support was frustrating, but Pardoll says it did have one salutary effect: It made immunotherapy more collegial and less back-biting than a lot of other fields of science. "When you're a little bit ostracized I think it's just a natural part of human nature . . . to sort of say, 'Well, look, our field is going to be dead if we don't work together, and it shouldn't be about individuals,'" Pardoll said. He calls the recent explosion of successes "sort of like *Revenge of the Nerds*."

Elizabeth Jaffee, now an oncologist at Hopkins, was a biochemistry major in the 1970s when she first became inspired by early immunotherapy studies on mice.

WHILE THE EFFECT OF CHECKPOINT INHIBITORS CAN BE "EXCITING," JAFFEE SAYS, "YOU HAVE TO PUT IT IN PERSPECTIVE. A RESPONSE DOESN'T MEAN THEY'RE CURED."

In keeping with this collaborative spirit, immunotherapy researchers from six competing institutions have formed a cover band known as the CheckPoints, which performs at the annual meeting of the American Society of Clinical Oncology and in other venues. The band's harmonica player, James Allison of the M.D. Anderson Cancer Center in Houston, helped set immunotherapy on its current course with his work on checkpoint inhibitors in 1996, when he was at Berkeley. He was the first to prove that blocking the checkpoint CTLA-4 (shorthand for "cytotoxic T-lymphocyte antigen") with an antibody would generate an anti-tumor response. As Pardoll puts it, once Allison demonstrated that first checkpoint system, "we had molecular targets. Before that, it was a black box."

The checkpoint system, when it's working as it should, is a simple one: invader is detected, T-cells

proliferate. Invader is destroyed, T-cells are deactivated. If T-cells were to stay active without an invader or a rogue cell to fight, they could create collateral damage to the body's own tissues. So the immune system contains a braking mechanism. Receptors on the surface of the T-cells look for binding partners on the surfaces of other cells, indicating that those cells are healthy. When these receptors find the proteins they're looking for, they shut the T-cells down until they spot a new invader.

Cancer cells are able to do their damage partly because they co-opt these checkpoints—in effect, hacking the immune system by activating the brakes. This renders the T-cells impotent, allowing the cancer cells to grow unimpeded. Now scientists are figuring out how to put up firewalls that block the hackers. Checkpoint inhibitors deactivate the brakes and allow the T-cells to get moving again. This lets the body kill off the cancer cells on its own.

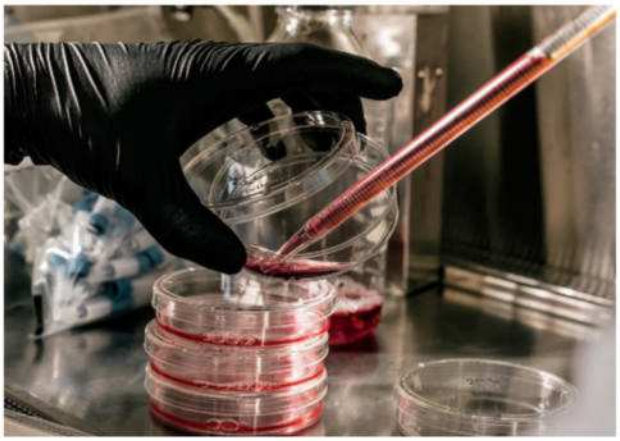
Suzanne Topalian, who is Pardoll's colleague at the Bloomberg~Kimmel Institute (and also his wife), played a key role in identifying another way the immune system could be used to fight cancer. After working as a fellow in Rosenberg's lab, she became the head of her own NIH lab in 1989 and moved to Johns Hopkins in 2006. At Hopkins, she led a group of investigators who first tested drugs blocking the immune checkpoint receptor PD-1—short for "programmed death-1"—and the proteins that trigger it, PD-L1 and PD-L2.

In 2012, Topalian shared some highly anticipated findings at the annual meeting of the American Society of Clinical Oncology. In a trial of the PD-1 inhibitor nivolumab, a high proportion of the 296 subjects had shown "complete or partial response": 28 percent of those with melanoma, 27 percent of those with kidney cancer, and 18 percent of those with non-small-cell lung cancer. These responses were remarkable, considering that the patients all had advanced cancers and had not responded to other treatments. Many had been told before the trial that they were weeks or months away from death. In two-thirds of the patients, the improvements had lasted for at least one year.

Topalian's talk came after a presentation by Scott Tykodi from the Fred Hutchinson Cancer Research Center in Seattle, who described another study with similarly impressive results. Later that day, the *New York Times* quoted an investment adviser saying checkpoint inhibitors "could be the most exciting clinical and commercial opportunity in oncology."

STILL, TOPALIAN was mystified by something. In the process of testing a particular checkpoint inhibitor, she and her colleagues had found that some patients responded much more dramatically than others. Colon cancer was especially puzzling. In two trials, Topalian and her colleagues had treated a total of 33 patients with advanced colon cancer with a PD-1 inhibitor. Of those, 32 had had no response at all. But early in the first trial, there was one patient who had a complete tumor regression that lasted several years. With results like these—one success, 32 failures—many scientists might have dismissed the drug as useless for advanced colon cancer. But Topalian kept wondering about that one patient.

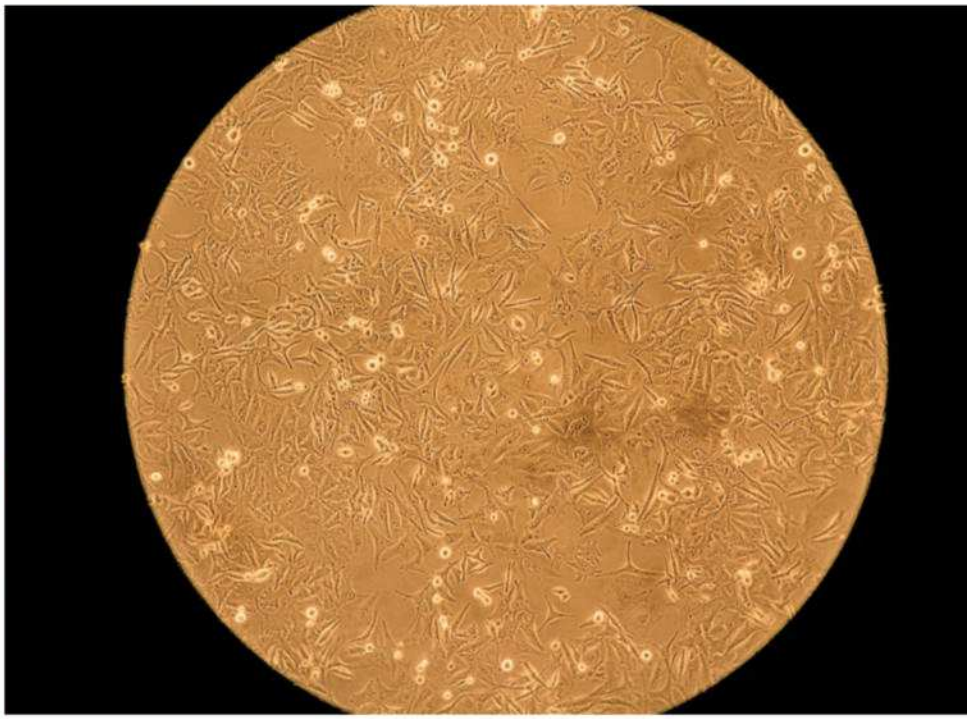
Sometimes she would muse about that patient



Top row: Cells are used for immunotherapy research at the Bloomberg-Kimmel Institute; research associate Shuming Chen and lab manager Tracee McMiller pull boxes of the frozen cells from vats of liquid nitrogen. Bottom row: Annie Wu, a PhD student working at the Bloomberg-Kimmel Institute, examines stained pancreatic tumor cells taken from mice; refrigerators store materials from in-progress research; melanoma cells are seen through a microscope at Topalian's Bloomberg-Kimmel lab.


Shuming Chen
Surgery


TARA



with Pardoll. (They have been married since 1993 and run collaborating labs at the Bloomberg-Kimmel Institute, where Topalian is also an associate director.) Pardoll's thoughts turned to a Hopkins colleague: Bert Vogelstein, one of the world's leading experts on cancer genetics, and a specialist in colon cancer. "Let's go talk to Bert," Pardoll suggested to Topalian. This was in early 2012.

So the couple, along with a few lab mates, took the elevator one flight up from Pardoll's lab to Vogelstein's. They described their recent work to the people up there, including their odd finding of the single cancer patient who responded to a checkpoint inhibitor.

"Was the patient's tumor MSI-high?" asked Luis Diaz, a cancer geneticist then in Vogelstein's research group.

MSI stands for microsatellite instability. A high score would indicate that the patient's tumor had a defect in the DNA proofreading system. When that system functions correctly, it winnows out errors that occur during DNA replication. When it fails, a bunch of mutations accumulate in the tumor cells. From an immunological point of view, a high "mutation load" could be helpful, since it would make cancer cells easier for the immune system to recognize as foreign—almost as if the tumor cells had a "hit me" sign pinned on them.

Topalian contacted the mystery patient's Detroit-based oncologist, asking for the tumor's MSI. Sure enough, it was high. Pardoll calls this the study's "eureka moment."

tients. Pembrolizumab, sold under the commercial name Keytruda, had already been approved for other specific cancer types. (It became famous in 2015 when former President Jimmy Carter used it to recover from metastatic melanoma that had spread to his liver and brain.) But based on the results of the Bloomberg-Kimmel Institute study, the FDA made Keytruda the first drug ever to be approved for all tumors with a particular genetic profile—regardless of where they showed up in the body.

"This is a complete paradigm shift," says Pardoll. With this historic step, he adds, the FDA has made checkpoint inhibitors "the first cancer-agnostic approach to treatment."

Dung Le, a prolific researcher, was an author on eight studies in 2017. Two of them dealt with arthritis, a possible side effect of checkpoint inhibitors.

IMMUNOTHERAPY IS POISED to become the standard of care for a variety of cancers. The work being done now is forcing a reconsideration of basic tenets of clinical oncology—for instance, whether surgery should be a first line of treatment or should come after drugs like Keytruda.

Many questions still remain. Elizabeth Jaffee, a member of the "cancer moonshot" panel convened by then-Vice President Joseph Biden in 2016, says she's conscious of the danger of overselling a treatment. While the effect of

"UNLIKE THE STATIC, BRUTE FORCE ATTACKS WE'VE ATTEMPTED ON CANCER IN THE PAST," SAYS ONE LEADING IMMUNOTHERAPY RESEARCHER, "THIS IS A DYNAMIC SYSTEM THAT CAN OUT-EVOLVE THE TUMOR."

The researchers went on to confirm what the geneticists had suspected: the genetic profile known as "MSI-high" makes tumors extraordinarily responsive to checkpoint inhibitors. Only about 4 percent of all advanced solid tumors are MSI-high, but because roughly 500,000 patients in the U.S. are diagnosed with advanced cancer each year, that means about 20,000 could benefit. The genetic profile is most common in endometrial cancer, of which about 25 percent are MSI-high. It is quite rare in other cancers, such as those of the pancreas and breast. Colon cancer falls into the middle range: about 10 to 15 percent of all colon cancers are MSI-high.

In May 2017, the U.S. Food and Drug Administration approved the treatment developed at the Bloomberg-Kimmel Institute to target MSI-high pa-

checkpoint inhibitors can be "exciting," she says, "you have to put it in perspective. A response doesn't mean they're cured. Some may have a year of response," but the cancer might start growing again.

The treatments can also have troubling side effects. When T-cells are unleashed, they can misidentify the patient's own cells as invaders and attack them. "Usually the side effects are low-grade rashes or thyroiditis or hypothyroidism," Le says. Generally, they can be controlled by taking the patient off immunotherapy for a while and prescribing steroids.

Sometimes, though, the immune system's reaction can inflame the lungs, colon, or joints or shut down particular organs. A patient can get treated for cancer and come out with rheumatoid arthritis, colitis, psoriasis or diabetes. The most extreme side effects "are

high-risk and fatal," Le says. And they can sometimes flare up without warning—even weeks after the immunotherapy has stopped.

"We had a patient recently who had a complete response"—that is, the cancer was pretty much gone—"who had a fatal event while off therapy," Le told me. It's very rare for such a serious side effect to occur, says Le. "Most patients don't get those things, but when they do, you feel awful."

Another hurdle is that the six checkpoint-inhibitor drugs now on the market work on only two of the checkpoint systems, either CTLA-4 or PD-1. But the T-cell has at least 12 different brakes, as well as at least 12 different accelerators. The particular brakes and accelerators required to fight off the disease might be different from one cancer type to another, or from one patient to another. In short, there are a lot of possibilities that haven't yet been thoroughly investigated.

More than 1,000 immunotherapy trials are now underway, most of them driven by pharmaceutical companies. Many of the treatments they're testing are different proprietary variations of similar drugs. The "cancer moonshot" program—now called Cancer Breakthroughs 2020—is hoping to streamline this research by creating a Global Immunotherapy Coalition of companies, doctors and research centers. With all the money to be made, though, it might prove difficult to turn competition into cooperation. The nerds aren't a band of outsiders anymore.

Sean Parker, the Silicon Valley entrepreneur, is trying a more open-source approach. Parker rose to fame in 1999 when he co-founded the free song-swapping platform Napster. So it's no surprise that he believes sharing information is crucial to moving immunotherapy forward. In 2016, he launched the Parker Institute for Cancer Immunotherapy with $250 million in funding from his own foundation. His goal is to collect ongoing data from the six major cancer centers in his consortium, plus individuals at several other centers. The parties sign agreements that give them ownership of their own work, but let other researchers see certain anonymized information they gather.

The Parker Institute's CEO, Jeffrey Bluestone, is an immunologist at the University of California, San Francisco who is also involved in research on Type 1 diabetes and studies immune tolerance in organ transplantation. With his understanding of how the immune system can backfire, he's been particularly instrumental in finding ways to activate T-cells without causing dangerous side effects. In a 2016 speech at the annual tech conference Dreamforce, Bluestone called the immune system "an intelligent technology platform that is there for us to decode, and ultimately, utilize

A DNA-Based Attack

A newly approved treatment is a milestone in gene therapy for cancer

DIMAS PADILLA, A 44-YEAR-OLD SALES representative who lives near Orlando, hoped he had seen his last battle with non-Hodgkin's lymphoma. But while driving one day, he felt his seatbelt pressing against his neck more tightly than usual.

"Right then my worst fear came into my mind," Padilla says. "I didn't want to say it, but I knew it." One of his lymph nodes had swollen to the size of a golf ball—his cancer was back for the third time, and all his therapy options were exhausted. Or so he thought until he met Frederick Locke, an oncologist who leads the immune cell therapy initiative at Moffitt Cancer Center in Tampa.

Locke was studying an experimental treatment called chimeric antigen receptor T-cell therapy (CAR T-cell therapy for short), in which a patient's own immune-system cells are genetically enhanced to fight cancer. Padilla first had his T-cells harvested from his blood. Technicians then inserted a novel gene into those cells, which responded by producing new surface receptors that would seek and latch onto a specific protein target on his lymphoma cells. Doctors put these customized T-cells back into Padilla's bloodstream.

"It really was remarkable," Locke says. "His tumor on his neck just shrunk away within a week or two."

A year later, the tumor still hadn't returned. Padilla marked the anniversary by taking his family to the beach to "celebrate life." He has now been tumor-free for 18 months. About half of the 101 patients involved in the study had a complete remission—a success rate four or five times higher than could be expected with existing treatments. The results convinced the Food and Drug Administration this past October to approve this version of the treatment, called Yescarta, for certain types of B-cell lymphoma. It's only the second gene therapy the agency has greenlighted for cancer.

"These are patients with an abysmal prognosis, really without hope," says Locke. "And now with this therapy we're really able to give them a chance."

Such success doesn't come without risk. For the time being, Yescarta is available only for patients for whom at least two other forms of therapy have failed. Like other forms of immunotherapy, it can produce dangerous side effects, including neurological toxicity. Three patients in the Yescarta trial died from severe cases of cytokine release syndrome (CRS), which can occur when proteins called cytokines are released by active white blood cells and cause life-threatening inflammation.

This syndrome is typically reversible, Locke says. Padilla experienced a high fever and temporary memory loss. At one point, he was unable to recall the year of his birth or write his own name. Yet he was back to normal in about two weeks.

The treatment was worth the discomfort, according to Padilla. "The other option, if I didn't do anything," he says, pausing—"That was it." **—ZOE SAYLER**

to beat cancer. Unlike the static, brute force attacks we've attempted on cancer in the past, this is a dynamic system that can out-evolve the tumor."

Topalian also sees large databanks as a key part of immunotherapy's future. "That way, you can connect data about a tumor biopsy with clinical characteristics of that patient—for instance, how old they are, and how many other treatments they'd had before the biopsy. You can also link in DNA testing, immunological markers, or metabolic markers in a tumor. The vision is that all of this data, emanating from a single tumor specimen, could be integrated electronically and available to everyone."

Meanwhile, Topalian is continuing to work with Hopkins experts in genetics, metabolism, bioengineering and other areas. One of her colleagues, Cynthia Sears, recently received a grant to study biofilms—the colonies of bacteria that grow in the colon and can either promote or prevent cancer growth. Sears is looking at how a particular "tumor microbial environment" affects the way a patient responds—or fails to respond—to cancer immunotherapy.

"The immune system is the most specific and powerful killing system in the world," says Pardoll, summing up the state of immunotherapy in early 2018. "T-cells have an amazingly huge diversity, and 15 different ways to kill a cell. The basic properties of the immune system make it the perfect anti-cancer lever." But science won't be able to fully mobilize that system without the help of myriad specialists, all working from different angles to piece together the incredibly complex puzzle of human immunity.

ON A FRIGID SATURDAY MORNING in January, I met Miss Vanessa in her immaculate living room. "It's been a journey," she told me. "And with each step, I'm just so grateful that I'm still living."

Miss Vanessa, who will turn 64 in July, had assembled a posse to join our conversation. It included her aunt, her next-door neighbor, her best friend, and her children, Keara and Stanley. On a dining chair, keeping close watch on his grandmother, was Keara's 16-year-old son Davion; sprawled across the staircase that led up to the bedrooms was her 20-year-old son Lettie. Everyone had come to make sure I understood how tough Miss Vanessa is, and how loved.

Today, after a year and a half of treatment with Keytruda, Miss Vanessa's tumors have shrunk by 66 percent. She still tires easily, and she has trouble walking due to the nerve damage caused by her earlier rounds of chemotherapy. She says her feet feel as if she's standing in sand. But she's deeply grateful to be alive. "I'm on a two-year clinical trial, and I asked Dr. Le what's going to happen when the two years is up," Miss Vanessa told me. "She said, 'I got you, you're good, we're just going to keep things going as is.'" According to Miss Vanessa, Le told her to focus on spending time with the people she loves, doing the things she loves to do.

Miss Vanessa at home. Her grandson Lettie, reflected in the mirror, is one of many relatives who stop by regularly to check up on her.

For Miss Vanessa, that means cooking. These days Keara has to do a lot of the prep work, because the nerve damage also affected Miss Vanessa's hands, making it hard for her to wield a knife or vegetable peeler. She wears gloves to grab ingredients from the refrigerator—the nerve damage

again, which makes her extremities highly sensitive to cold. Sometimes in the middle of making a meal, she needs to go lie down.

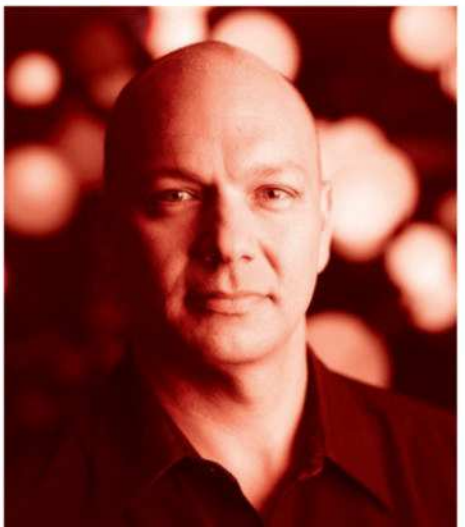
Still, Miss Vanessa told me she thinks of every day as a blessing, and listed the things she has been lucky enough to witness—things she'd feared, just a few years ago, she would never live to see. "I'm here to see Lettie graduate from college," she said. "I'm here to see Davion go into a new grade. I'm here to watch Zion start kindergarten . . . " She trailed off, hardly daring to think about the milestones that await Zion's younger brother and sister, ages 1 and 2.

"When it's your time, it's your time—you can't change that," said Stanley, gazing at his mother. "Everybody knows you live to die. But I don't think it's her time." ◆

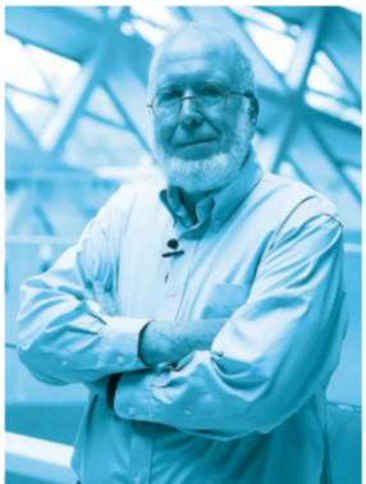
TOMORROW LAND

THE TECH TITANS OF SILICON VALLEY TELL US WHAT THEY THINK IS COMING SOON TO A PLANET NEAR YOU—FROM BRAIN IMPLANTS TO ROBOT SEX

BY
Adam Fisher



Left to right, from top row: Jim Clark, Carol Bartz, Larry Page; Steve Wozniak, Nolan Bushnell, Jaron Lanier; Brenda Laurel, Marissa Mayer; Tony Fadell, Kevin Kelly and Tiffany Shlain



IN 1965, A COMPUTER-CHIP DESIGNER NAMED Gordon Moore published a soon-to-be-famous paper predicting that computing power—the number of logic gates that could be packed onto a silicon chip—was about to begin doubling every year. He was right, in a huge way. What was soon called Moore's Law led to the transformation of some muddy real estate south of San Francisco into Silicon Valley, and we've been on a rocket ride of innovation ever since. The personal computer, the internet, the smartphone. The rate of change codified in Moore's Law has been slowly winding down—Moore acknowledged as much in 2015, on the 50th anniversary of his paper—and yet each blast of innovation still seems to be more disruptive than the last. Today, the Valley is no longer symbolized by two guys tinkering in a garage: It's defined by thousands of start-ups and hundreds of billions of dollars of venture capital looking to fund new ideas. So what's next? Where will Silicon Valley take us in the next two decades? I've posed those questions to futurists, computer scientists, academics, tech executives—and to men and women who shaped the world we live in today. Here is a distilled version of what they had to say.

KEVIN KELLY *author, most recently, of* The Inevitable: The biggest invention in Silicon Valley was not the transistor but the start-up model, the culture of the entrepreneurial start-up.

MEGAN SMITH *chief technology officer of the United States, 2014-17*: I grew up in it. It's extraordinary. An entrepreneurial culture of, like, "Hey, how can we solve this?" And really caring about helping each other.

CAROL BARTZ *former CEO of Autodesk and Yahoo*: It really is just this need to change as fast as possible to enable the next great thing. We don't even have to imagine the next great thing yet. We just have to get the tools to do something and use trial and error until we have the next great thing.

SCOTT HASSAN *co-author of the code for Google's search engine, founder of the research lab Willow Garage*: I try not to predict the future very much, but the one thing I know for certain is that in the future, there are going to be more computers, they're going to be faster, and they're going to do more things.

TONY FADELL *co-inventor of the iPod, founder of Nest Labs*: You're going to see every single industry, no matter how behind the times they are, adopting technology—deep technology.

HASSAN: Eventually computers are going to do everything. I don't think anything is safe. Nothing.

KRISTINA WOOLSEY *known as the "mother of multimedia" for her work as director of Atari's research lab and co-founder of Apple's multimedia lab*: Technology is changing fundamental things. It changes where you can live and work; it changes who you know; it changes who you can collaborate with. Commerce has completely changed. Those things change the nature of society.

FADELL: Change is going to be continual, and today is the slowest day society will ever move.

HASSAN: Never, ever try to compete with a computer on doing something, because if you don't lose today, you'll lose tomorrow.

BARTZ: We are very arrogant out here that nothing can change unless technology is involved, and technology will drive any business out there to a disruption point.

ANDY HERTZFELD *one of the software engineers behind the Macintosh computer, a co-founder of General Magic*: Right now the Valley is particularly excited about two things: one of them is machine learning; incredible progress has been made in machine learning the last three or four years. A broader way of saying it is artificial intelligence.

MARISSA MAYER *Google employee number 20 and the last CEO of Yahoo*: I'm incredibly optimistic about what AI can do. I think right now we are just at the early stages, and a lot of fears are overblown. Technologists are terrible marketers. This notion of *artificial* intelligence, even the acronym itself, is scary.

TIFFANY SHLAIN *futurist, Emmy-nominated filmmaker, founder of the Webby Awards*: There's all this hysteria about AI taking over. But here's the thing: The skills we need most in today's world—skills like empathy, creativity, taking initiative and cross-disciplinary thinking—are all things that machines will never have. Those are the skills that will be most needed in the future, too.

MAYER: If we'd had better marketing, we would have said, "Wait, can we talk about *enhanced* intelligence or *computer-augmented* intelligence, where the human being isn't replaced in the equation?" The people who are working on artificial intelligence are looking at how they can take a repetitive menial task and make a computer do it faster and better. To me, that's a much less threatening notion than creating an artificially intelligent *being*.

HERTZFELD: The second thing Silicon Valley is particularly excited about right now is artificial reality, or you might say mixed reality or whatever you want to call it.

KELLY: That VR [virtual-reality] vision of the alternative world is still there, but the new thing is this other version of "augmented" or "mixed" reality, where artificial things are inserted into the real world, whether they be objects or characters or people.

HASSAN: VR blocks off your field of vision, and everything has to be reconstructed digitally. And so MR, which is mixed reality, is a technology that can selectively draw on any part of your vision. It can actually include all your vision, if that's what's required. MR is, I believe, the next step in how we interface with computers and information and people. It's all going to be through mixed reality. And VR is a special case of mixed reality.

NOLAN BUSHNELL *founder of Atari and, with it, the video-game industry*: All of this is on a

GORDON MOORE (in 1980): The son of a sheriff, he laid down the law that defined the digital revolution.

PP. 56-57: LEFT TO RIGHT, FROM TOP ROW: STEVE KAGEN / GETTY IMAGES; PETER DASILVA / THE NEW YORK TIMES / REDUX; DAVID PAUL MORRIS / BLOOMBERG / GETTY IMAGES; MICKEY PLEGER / THE LIFE IMAGES COLLECTIONS / GETTY IMAGES; TONY KORODY /SYGMA / GETTY IMAGES; ISOLDE OHLBAUM / LAIF / REDUX; HILARY HULTEEN; SIMON DAWSON / BLOOMBERG / GETTY IMAGES (2); VCG / GETTY IMAGES; HENRY GARFUNKEL / REDUX

"CHANGE IS GOING TO BE CONTINUAL, AND TODAY IS THE SLOWEST DAY SOCIETY WILL EVER MOVE."

continuum, and right now augmented reality is a little bit harder than virtual reality, technically.

STEVE WOZNIAK *the technical genius behind the Apple II computer and leader of the personal-computer revolution*: Because of Moore's Law, we always have more bits and more speed to handle those more bits on the screen. Well, we now have finally gotten to the point where we have enough computer power that you can put the screen on your head, and it's like you're living in a different world; and it fools you. It's enough to fool the brain.

BUSHNELL: I've seen how technology has moved from Pong to what we're playing today. I expect the same kind of pathway to virtual reality, and I think that 20 years from now we will be shocked at how good VR is. I like to say we are at the "Pong phase" of virtual reality. Twenty years from now, VR is going to be old hat. Everybody will be used to it by then. Maybe living there permanently.

BRENDA LAUREL *virtual reality's first theorist and one of its inventors*: The only way I can see that happening is if we completely trash this planet.

JIM CLARK *co-founder of Silicon Graphics, Netscape and other companies*: Nolan is a good friend, I know him well, and he can get hyperbolic. I do not think people are going to be living in virtual reality. That might be true in a hundred years—not in 20.

BUSHNELL: So when is VR indistinguishable from reality? I've actually put a little plot together on that. I think we're about 70 percent of the way there visually. I think we're 100 percent of the way there with audio. I think we're 100 percent of the way there in smell. I think we're just scratching the surface on touch and fooling your inner ear, and acceleration, and the thing that I think will break the illusion will be food. I think that's going to be the hardest one to simulate in VR. So when you see the guy in *The Matrix* having a great bottle of wine and steak? That's going to be hard.

JARON LANIER *coiner of the term "virtual reality" and a founding father of the technology*: On some spiritual level, it seems terribly wrong to say, "Well, we know enough about reality that living in this simulation is just as good." Giving up that mystery of what the real world is seems like a form of suicide or something.

CLARK: Plus I'd rather have real sex than virtual sex.

BUSHNELL: That's really a matter of haptics—a full haptic body suit, where the suit simulates temperature and pressure on your skin, and various things. . . .

LAUREL: You know what? If the boys can objectify software instead of people, then it's good for everyone—except the boys.

HASSAN: That same type of technology will be used in tele-operated robots; some people call them Waldos. Think of this device as a set of arms that rolls around, that's able to do stuff—two hands that can be manipulated from afar. Let's say it fits where your dishwasher used to be, and whenever you need it, it comes out of there and it unfolds and it's operated by somebody else in another location that has expertise that you want at that time. You want dinner made? Well, it's just remote-operated by a chef, in some type of rig, so that when they move their arms, the robot moves its arms, in the exact same way. . . . Then that same Waldo, when that person is done with making dinner for you, instantly switches over to this other person who loves to clean up, and then they go and clean up the whole kitchen for you.

BUSHNELL: In 20 years, 80 percent of homes will have some kind of a robot.

BARTZ: Every inflection point really followed from the fact that you could make something affordable, so that the public or industry could do something with it. You could get this in the hands of more people, which meant it was a bigger market, and on and on, and off you went.

HASSAN: They'll probably be the same price as a refrigerator. It's going to be one of those things: You got your car, you got your house and you got your Waldo. But the cool thing about that is, once that kind of stuff comes out, then people will write all these applications that CONTINUED ON PAGE 78

P. 58: COURTESY OF INTEL

THE BUZ

BY *Franz Lidz*

HERE IS NO PIE IN THE SKY. THERE'S NO BEER, EITHER.

In 2007, following confirmation that two of its astronauts had flown three sheets to the ozone, NASA formally banned crews from imbibing in orbit. These days any rocketeer wishing to get staggeringly pie-eyed and maybe moon the Moon will have to hitch a ride with another space agency altogether.

It's equally sobering to note that carbonated beverages are outlawed on the International Space Station. Gas bubbles in a carbonated drink don't act the same as on gravity-rich Earth. Instead of floating to the top, the bubbles lie there, evenly distributed in the liquid. Maybe that's just as well. The drink would be a frothy mess. To rework the lyrics of David Bowie's "Space Oddity," the head on a brewski poured from a tin can far above the world would float in a most peculiar way. How peculiar? Tristan Stephenson, author of *The Curious Bartender*, has speculated that the bubbles in this slop would "flocculate together into frogspawn-style clumps."

Frogspawn would make a great craft beer name, if it isn't one already. And though weightlessness might make falling off one's bar stool safer, as the British magazine *New Scientist*

STRAP ON YOUR BEER GOGGLES AND JOIN US ON A HOPS-FUELED ROCKET RIDE TO INSOBRIETY...AND BEYOND!

PHOTO ILLUSTRATION BY *David Arky*


ZED
LIGHTYEAR

once delightfully explained, "without gravity to draw liquids to the bottoms of their stomachs, leaving gases at the top, astronauts tend to produce wet burps." It ain't easy to belch in outer space.

All this hasn't stopped the typographical Frankenstein known as Anheuser-Busch InBev from devising plans to boldly brew where no man has brewed before. Last December, as part of the macrobrewery's microgravity research, the makers of Budweiser had Elon Musk's SpaceX rocket transport 20 barley seeds to the ISS. Mindful of NASA's long-term goal to send humans to Mars by the 2030s, space station scientists conducted two 30-day experiments, one on seed exposure and the other on barley germination. In a statement, Bud announced that its long-term goal is to become the first beer of the red planet.

It's a well-known fact that water, a basic component of beer, is in short supply outside of Earth. But satellite imaging has confirmed that vast glaciers of ice exist below Mars' rocky surface. "Several universities are working on mining and mining technology for Mars, including mining water," says Gary Hanning, who heads Budweiser's innovation and barley research team in Fort Collins, Colorado. "The miners will have to bring out the ice, thaw it, clarify it, purify it and all those other good things. But it's still going to be an extraordinarily limited raw material." Houston, we have a drinking problem.

We all know that Budweiser travels well, but . . . 49 million miles! According to NASA, shipping costs to space can run about $10,000 a pound. "The cost per gallon of beer is going to be outrageous," Hanning concedes. "We're going to want to produce our own food and crops and products there, and not haul them back and forth all the time." It's been argued that you can't really enjoy a cold one when the temperature outside is minus 195 degrees, and that beer crops won't grow in a place inhabited only by sand and iron dust. "Argued by whom?" asks Steve Rushin, author of the witty, beer-centric novel *The Pint Man*. "Those are the kind of arguments you have on Earth, in a bar, after one too many."

In the blue planet's taprooms, Budweiser's extraterrestrial dilly-dillying has raised a star-fleet of existential questions. If Matt Damon could live off potatoes grown in his own poop in *The Martian*, could Mars colonists live off Bud? Would self-driven Mars rovers eliminate the need for designated drivers? Will robot beers be made by robots, or consumed by them? And, at a time when the names of small-batch brands are becoming increasingly otherworldly (Space Cake, Black Hole Sun, Totally Wicked Nebula, Klingon Ale), what are beers' final frontiers?

A cynic might say the reason Budweiser is trying to stake out territory on the fourth rock from the Sun is that its turf on the third is slowly shrinking. Last year, for the first time in decades, Bud was not among the top three best-selling beers in America. Sales have slumped for all industrial-scale brews, due in no small part to the rapid fermentation of craft beers.

Beer geekerati have long disparaged the conglomerate's brews as watery and flavor-challenged while championing traditional, local tipples. The intense infusions (blood orange, ghost peppers), esoteric additives (stag semen, crushed lunar meteorites) and sometimes preposterous ingredients (yeast grown in a brewmaster's beard, coffee beans predigested by elephants) supposedly lead to more complex flavors than the beer majors can provide. Even Elvis—and perhaps only Elvis—might have been tempted by Voodoo Doughnut Chocolate, Peanut Butter & Banana Ale.

Steve Rushin predicts beer is fated to become even more locavore-ish (locavore-acious?) than it is now. "In the future you'll choose from beers brewed in your own neighborhood, possibly your own street, maybe your own house," he says. "You may already be living in this future."

For its part, Budweiser seems to be living in the future of *Total Recall*, a 1990 sci-fi thriller that envisioned what bar service on Mars will look like in 2084 (neon Coors Light and Miller Lite signs, and not a craft beer in sight). Asked if he's distressed that the first beer poured on Mars may be a pedestrian Bud, James Watt, co-founder of the Scottish "punk" beer company BrewDog, growls: "It's not so bad if it means it leaves this planet." Despite the King of Beers' plans for interplanetary conquest, Watt doubts it will one day become the King of Galactic Beers. "You can't make much beer with 20 seeds of barley," he says. "Call me when Bud is growing hops on Mars."

HOPS FARMERS ON MARS WILL HAVE TO PURGE THE POISON FROM THE SOIL BEFORE BUDWEISER'S CLYDESDALES DRAW PLOUGHS THROUGH IT.

AS IT TURNS OUT, A GROUP of students at Villanova University have done just that—more or less. A few months back, Edward Guinan had one of his classes experiment to see which terrestrial plants would thrive in the dense, cakey soil of Mars. "I ruled out Venus, a pressure cooker with sulfuric acid rain," he recalls. "The average temperature is around 865 degrees: It would be like trying to grow stuff in a pizza oven." He set out to approximate Martian dirt.

Most students who took part in Guinan's Red Thumbs Mars Garden Project sowed practical, nutritious vegetables with the soil simulant they developed. But one—surprisingly, not a frat boy—picked hops, the blossoms that impart a bitter bite to beer at the outset of production. The moderate, almost diffident Guinan vetoed marijuana, perhaps on the theory that space travelers would already be high enough.

Seedlings were cut with vermiculite and cultivated in a small patch of the campus greenhouse. Since less than half as much sunlight falls on the surface of Mars as on Earth, a mesh screen was erected to partially blot it out. In the thin light and thick soil, the hops flourished, but the potatoes—a staple of Damon's

CLOCKWISE STARTING FROM THE TOP LEFT: JACKIE MOLLOY (4); NASA

diet in *The Martian*—did not. "Hollywood!" mutters Guinan.

In his eyes, *The Martian*'s more unforgivable blooper pertained to perchlorate, a chemical compound that abounds in the Martian regolith. While perchlorates are toxic and interfere with the human body's ability to absorb iodine, researchers have also found that combining perchlorates with iron oxides and hydrogen peroxide—both found on Mars' surface—and irradiating it with UV light (as on Mars) greatly increases the toxicity. Inhaling or ingesting it can lead to thyroid problems and even death. Guinan says hops farmers on Mars will have to purge the poison from the soil before Budweiser's Clydesdales draw ploughs through it. "Fortunately," he says, "perchlorate is water-soluble; farmers could rinse it out of the soil." Spoiler alert: Perchlorate seemed to have no effect on Damon's character. "On the real Mars he would have died," Guinan says with a shrug. "The filmmakers didn't want audiences to know that little detail."

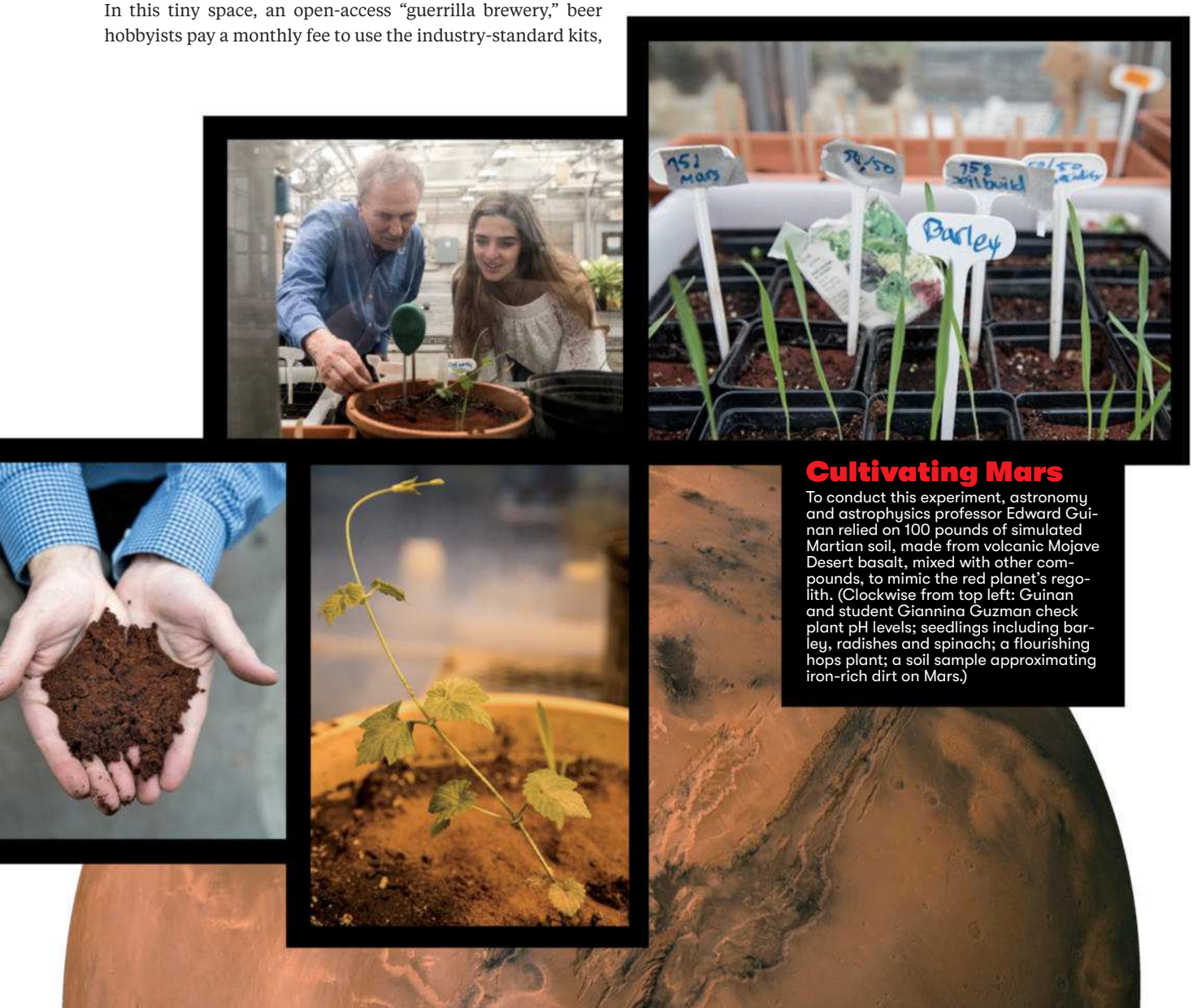
So much for movie science.

EARTH'S FIRST ROBO-BEER is generated by a machine-learning algorithm in a repurposed East London railway arch. In this tiny space, an open-access "guerrilla brewery," beer hobbyists pay a monthly fee to use the industry-standard kits, share tips with other members and flaunt their ingenuity. Rob McInerney surveys the DIY domain with a critical eye and a twitching nose. The co-creator of AI-brewed IntelligentX is looking at and sniffing ale simmering in a stainless steel tank.

The liquid is covered with creamy sand-colored foam, like toasted meringue on a vast juicy pie. "IntelligentX is beer that learns," McInerney says, flatly. The archway is heady with a smell of hops and malt as pungent as a newly mowed field. "You drink more, you get less smart, but IntelligentX is going to get smarter."

McInerney's potable is brewed by Automated Brewing Intelligence (ABI), a program that develops recipes based on algorithms cranked out with the help of consumer feedback. ABI continually rewrites the brewing process by altering variables like bitterness, alcoholic content and level of carbonation. The algorithm can also change the percentage of grain, malt, hops and encoded wild-card ingredients like lime and grapefruit.

"ABI acquires information about beer-making in much the same way as humans," says the 33-year-old McInerney, who completed his PhD in machine learning at the University of Ox-



Cultivating Mars

To conduct this experiment, astronomy and astrophysics professor Edward Guinan relied on 100 pounds of simulated Martian soil, made from volcanic Mojave Desert basalt, mixed with other compounds, to mimic the red planet's regolith. (Clockwise from top left: Guinan and student Giannina Guzman check plant pH levels; seedlings including barley, radishes and spinach; a flourishing hops plant; a soil sample approximating iron-rich dirt on Mars.)

"WE ELECTED NOT TO CONSTRUCT AN OUTDOOR SWIMMING POOL AND FILL IT WITH BEER. I LIKE MY BEER FRESH AND COLD, NOT SWEET. IT'S NOT ONLY KIDS WHO PEE IN POOLS."

ford. "It starts by observing the recipes that human brewers devise, then, through experience, comes up with its own ideas."

Previously, cans were stamped with a web address linked to a Facebook Messenger bot, which grilled imbibers about the beers they just sampled. Questions, which differ for each person who comes onto the platform, involve customer preference and flavor; answers are yes or no, while rankings are done on a scale of one to ten. Soon, says McInerney, users will be directed to the company's website, where data will be fed directly into the algorithms and to gather feedback. Once harvested, the data is interpreted by the ABI engine and pinged back to a master brewer, who tweaks the recipe.

The four basic brews of IntelligentX—golden, amber, pale and black—have already been through dozens of iterations. McInerney plans to open-source every unique recipe created by its algorithm so that home brewers can recreate their favorites. "Suddenly, you've got a product that's a culmination of people," he says, "not just some sort of machine creating stuff."

The area surrounding McInerney's brewery looks nothing like the East End where, in the late 1920s, George Orwell lived in the abject poverty he recounted in *Down and Out in Paris and London*. But McInerney has his own Orwellian fantasy: an iPub in which the pints are hooked up to ABI, which records how quickly a patron has guzzled, at what temperature and the volume of beer left in the glass. "I believe the future is a place where AI augments the skills of humans," he says. "IntelligentX uses AI to confer superhuman skills on brewers, enabling them to receive feedback faster than ever before."

If the destiny of beer is ABI, Sam Calagione, the founder of Dogfish Head, a U.S. craft brewery, says the concept makes him uneasy. "If you're just going off algorithms," he says, "you're not going to be able to innovate ahead of what's currently available. The context of what people say they want has to be relevant to what they've already tried."

BrewDog's James Watt agrees: "We love innovation in all aspects of what we're doing—the amount you could learn from that level of automation is pretty crazy. But brewing for the majority is brewing for nobody in particular, and you'd end up with the lowest common denominator beer, which excites just as little as it offends. And that's not worth sticking around for."

THE WORLD'S END IS A PUB in a 2013 British android-apocalypse film of the same name. It's a place where you might have enjoyed drinking the End of History, a 110-proof Belgian ale released eight years ago by Watt's brewery in Scotland. Only 12 bottles were made, and—to the outrage of animal rights activists—all were packed in taxidermied roadkill. "Beer pairs well with the apocalypse, for obvious reasons," observes Steve Rushin. "If you're the last man on earth, you'd probably want an End of History."

A Toast to Outer

IN CHRONOLOGICAL ORDER: COURTESY WEBSTER PRESBYTERIAN CHURCH; NASA (2); COURTESY SAPPORO HOLDINGS LTD.; COURTESY NINKASI BREWING COMPANY

1969

Buzz Aldrin, the aptly named Apollo 11 astronaut, takes communion in the hours before he and Armstrong embark on the first moonwalk. Wine and wafer are provided by Aldrin's Webster Presbyterian church. He describes the lunar sacrament in his 2009 memoir *Magnificent Desolation*: "I poured a thimbleful of wine from a sealed plastic container into a small chalice, **and waited for the wine to settle down as it swirled in the one-sixth Earth gravity of the moon."**

1994

Coors sponsors Kirsten Sterrett's space shuttle experiment devised to test the effects of microgravity on fermentation. After the results are in, the University of Colorado grad student gives the space suds a "little taste." The tiny sample isn't really enough to savor, she says, **"but why throw something like that away?"**

In his manifesto *Business for Punks: Break All the Rules—the BrewDog Way*, Watt posits himself as the Johnny Rotten of beer-making. Like ye olde Sex Pistols singer, the brewer's attitude tends to be edgy, willfully controversial and, in the extremity of its vision, directly political. *Business for Punks* counsels would-be entrepreneurs: "Don't be a pathetic leech scrambling around for crumbs off someone else's second-rate pie. Bake your own goddamn pie."

Watt carefully curated BrewDog's reputation as the provocateur of the craft beer revolution by staging brash stunts: launching the imperial-strength saison Make Earth Great Again in protest of the U.S. withdrawal from the Paris climate accord; provoking a trademark suit by the Presley estate by naming an IPA "Elvis Juice"; marking the wedding of Prince William and Kate Middleton by lacing a brew with Horny Goat Weed and christening it Royal Virility Performance.

Since establishing a beachhead in the North Sea port of Aberdeen nearly a decade ago, BrewDog has opened scores of wildly popular bars—bare brick, spray-painted graffiti—across the United Kingdom and around the world: Tokyo, Helsinki, Rome, São Paulo. Currently, the company is building The DogHouse, humanity's first craft beer hotel-cum-sour brewery. Located in Columbus, Ohio—a long pub crawl from 16 colleges and universities—and next to BrewDog's 100,000-square-foot brewhouse, the crowd-funded project will feature beer-infused breakfasts, lunches and dinners, with beers paired to every course. Amenities include hop-imbued massages.

The 32 rooms will feature Punk IPA taps and, in the showers, mini-fridges stocked with craft beers picked by Watt and BrewDog co-founder Martin Dickie. "We elected not to construct an outdoor swimming pool and fill it with beer," says Tanisha Robinson, CEO of BrewDog USA. "I like my beer fresh and cold, not sweet. It's not only kids who pee in pools."

Robinson can't decide whether the DogHouse is a hotel in a brewery or a brewery in a hotel. "It is the only fully immersive craft beer destination," she says. "It could be the future of beer tourism."

As Neil Armstrong might have put it: "That's one small stout for man, one giant lager for mankind." ◆

Space

*A **brief history** of extraterrestrial drinking*

1997

After a flash fire is extinguished aboard the Russian space station Mir, cosmonauts celebrate by breaking out their stashes of cognac. Though NASA forbids drinking in orbit, the Russians' attitudes are a bit looser; Mir is supplied with French and Armenian brandy. **Cognac was brought up on unmanned supply ships, and Russian ground control "winked at the practice,"** according to American astronaut Jerry Linenger, who was aboard Mir at the time but declined to imbibe. "On board there is a little bit [of cognac]," acknowledged Mir's commander, cosmonaut Vasily Tsibliyev. "It is needed because you can imagine the stressful situation on board."

2006

Japanese and Russian researchers send barley seeds to the International Space Station, to be planted in the Zvezda Service Module. After five months in the ionosphere, the grains are brought back to Earth, where Sapporo turns the fourth generation of those plants' descendants **into Space Barley, a six-pack of which fetched about $110**. Yet more proof that what happens in space doesn't stay in space.

2014

Colorado sixth-grader Michal Bodzianowski builds and dispatches a mini-microbrewery (a tube jammed with hops, yeast, water and malted barley) to the ISS in 2013 to see how the ingredients interact. The next year, a civilian rocket carries up six strains of brewer's yeast. Upon recovering the specimens, Oregon craft brewer Ninkasi steeps the payload in hazelnuts, star anise and cocoa nibs. **The resulting imperial stout is dubbed Ground Control.** It is now presumably Major Tom's favorite brew.

HACKING THE Future

A HIGH-WATTAGE TEXAS REPUBLICAN HAS BECOME THE UNLIKELIEST HERO OF **THE GREEN REVOLUTION**. BUT CAN HIS ELECTRIFYING EXAMPLE TRANSFORM AMERICA'S POWER STRUCTURE?

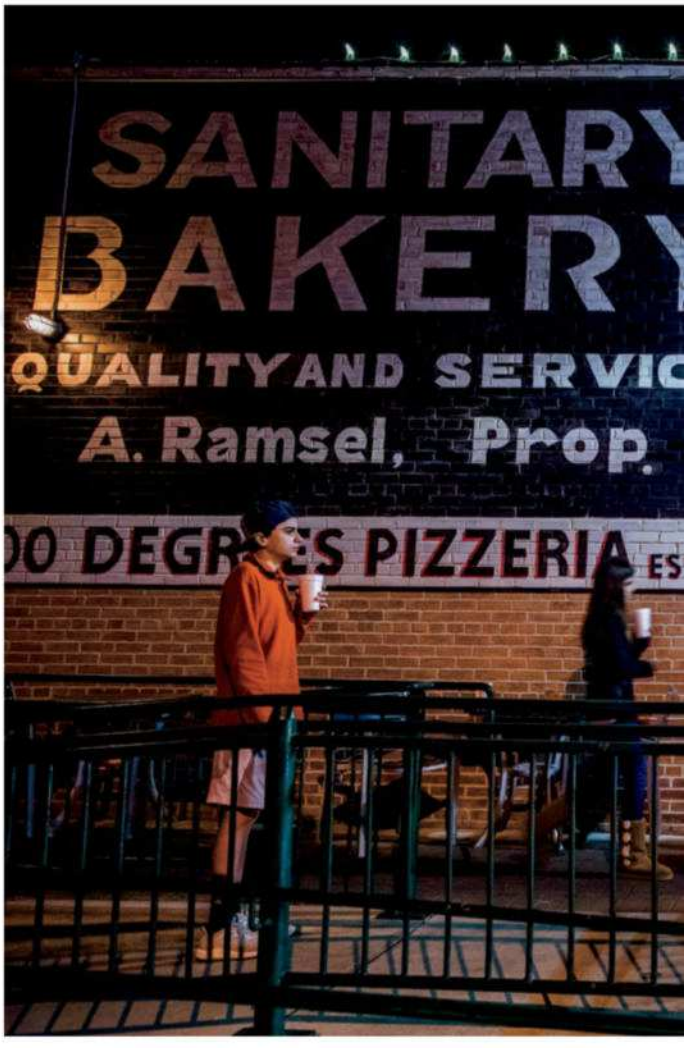
BY
Dan Solomon

PHOTOGRAPHS BY
Drew Anthony Smith

THE FUTURE'S SO BRIGHT

(He's Gotta Wear Shades)

"Cheaper electricity is better. Clean energy is better," says Georgetown Mayor Dale Ross.



DALE ROSS, THE MAYOR of Georgetown, Texas, has a big smile, a big handshake and a big personality. In last year's election, he won big, with 72 percent of the vote. The key to his success? "Without being too self-reflective," he says, "I just like people." He's a Republican, and his priorities are party staples: go light on regulation, be tough on crime, keep taxes low. But the thing that is winning him international renown is straight out of the liberal playbook—green power. Thanks to his (big) advocacy, Georgetown (pop. 67,000) last year became the largest city in the United States to be powered entirely by renewable energy.

Previously, the largest U.S. city fully powered by renewables was Burlington, Vermont (pop. 42,000), home to Senator Bernie Sanders, the jam band Phish and the original Ben & Jerry's. Georgetown's feat is all the more dramatic because it demolishes the notion that sustainability is synonymous with socialism and GMO-free ice cream. "You think of climate change and renewable energy, from a political standpoint, on the left-hand side of the spectrum, and what I've done is toss all those partisan political thoughts aside," Ross says. "We're doing this because it's good for our citizens. Cheaper electricity is better. Clean energy is better than fossil fuels."

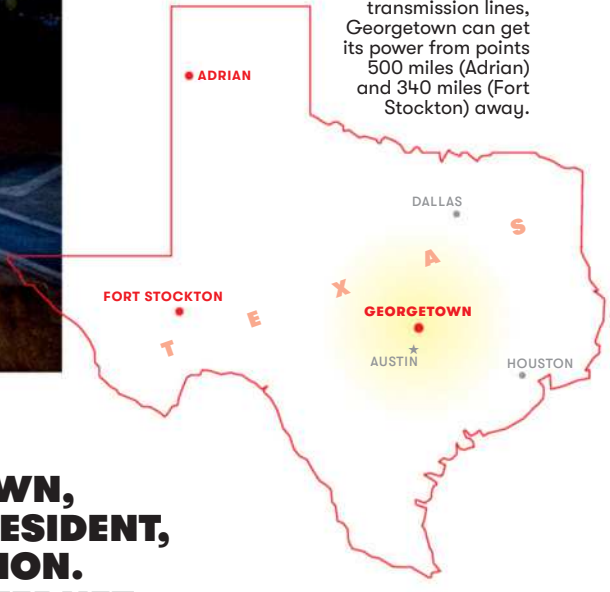
In a twist that has some Republicans in this oil- and gas-rich state whistling Dixie, Ross is now friends with Al Gore, who featured Ross in *An Inconvenient Sequel*, the 2017 follow-up to *An Inconvenient Truth*, his Oscar-winning documentary about global warming. "We bonded right away," Ross recalls. "I said, 'Mr. Vice President, we've got a lot in common. You invented the internet. I invented green energy.'" Trained as an accountant, Ross still works as one—being mayor of Georgetown is a part-time job—and there's no mistaking his zeal for the other kind of green. When conservatives complain about his energy politics, he is quick to remind them that the city has the lowest effective tax rate in Central Texas.

With Georgetown emerging as a brave new model for a renewable city, it makes sense to ask if others can achieve the same magical balance of more power, less pollution and lower costs. In fact, cities ranging from Orlando to St. Louis to San Francisco to Portland, Oregon, have pledged to run entirely on renewable energy. Those places are much larger than Georgetown, of course, and no one would expect misty Portland to power a light bulb for long with solar energy, which is crucial to Georgetown's success. But beyond its modest size, abundant sunshine and archetype-busting mayor, Georgetown has another edge, one that's connected to a cherished Lone Star ideal: freedom.

Georgetown's town square is dominated by 19th- and 20th-century storefronts, but the electric lights are powered by renewable energy.

Hot Spot

Thanks to Texas' investment in transmission lines, Georgetown can get its power from points 500 miles (Adrian) and 340 miles (Fort Stockton) away.



WHEN AL GORE CAME TO TOWN, THE MAYOR SAID, "MR. VICE PRESIDENT, WE'VE GOT A LOT IN COMMON. YOU INVENTED THE INTERNET. I INVENTED GREEN ENERGY."

AMERICA IS EMBRACING RENEWABLES, slowly. In 2016, Massachusetts passed a law promoting a huge investment in wind and hydropower; the first megawatt is expected to hit the grid in 2020. Early this year New York State announced plans to spend 12 years building the infrastructure for a $6 billion offshore wind power industry. Hawaii has pledged to be powered entirely by renewable energy—in 2045. Atlanta's goal is 2035 and San Francisco's is 2030. Typically, plans to convert to sustainable energy stretch on for decades.

Georgetown made the switch in less than two years.

Ross, something of a libertarian at heart, entered politics because he was ticked off that the municipal code prohibited him from paving the driveway to his historic home entirely in period-appropriate brick. (The code required some concrete.) He joined the city council in 2008 and was elected to his first term as mayor in 2014. He often likens the city to "Mayberry

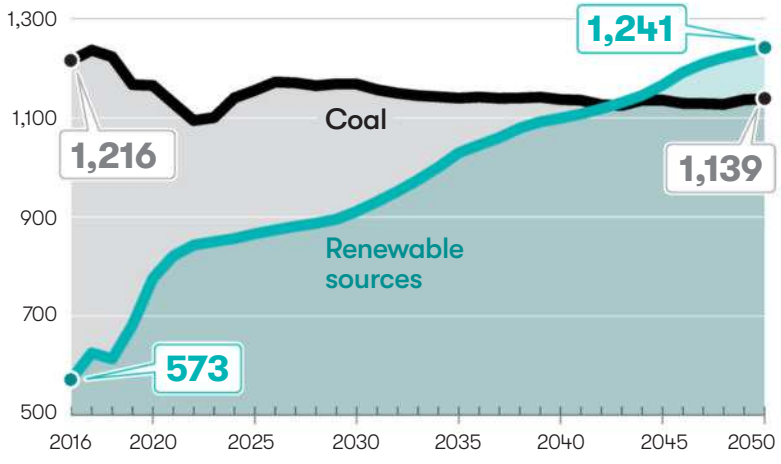
Capture the Sun, Harness the Wind

THE OUTLOOK FOR RENEWABLE ENERGY USED TO BE DIM. NOW, THANKS TO BETTER TECHNOLOGIES, IT'S INCANDESCENT

BY 5W INFOGRAPHICS

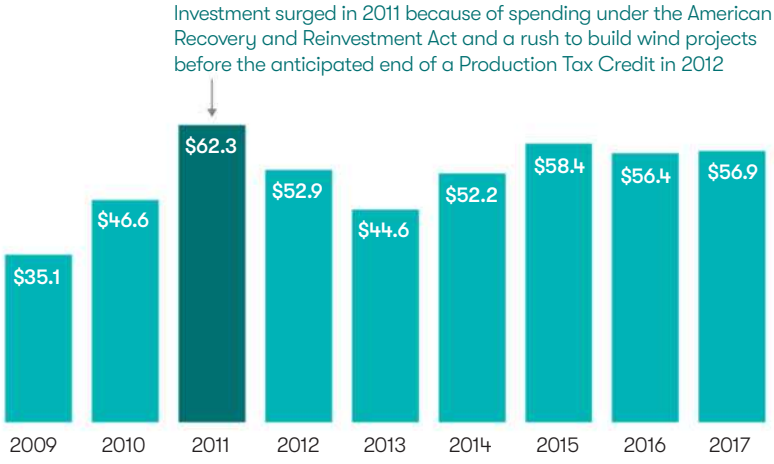
The Comparison to Coal

Projected sources of U.S. electricity generation, in billions of kilowatt hours



The Money Flow

New investment in clean energy in the United States, in billions of dollars



800

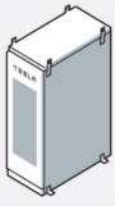
Energy storage, in megawatts, built in the United States in the last five years

AND

Energy storage, in megawatts, expected to be added in a single year by 2020

276

Weight, in pounds, of a Tesla Powerwall battery (residential use)



3,575

Weight, in pounds, of a Tesla Powerpack 2 battery (commercial use)

12,000

Estimated equivalent, in iPhone batteries, to the weight of one Powerpack 2

50,000

Coal-industry employees, 2016

102,500

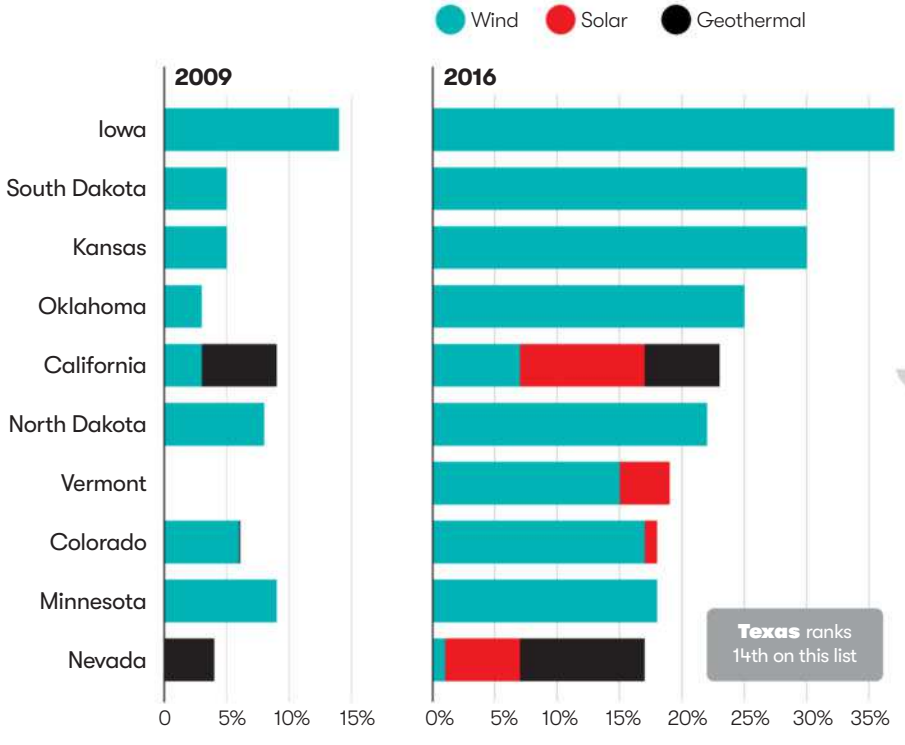
Wind-industry employees, 2016

260,000

Solar-industry employees, 2016

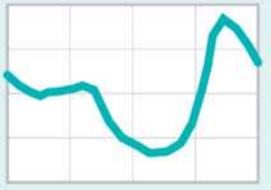
The Clean Top 10

States ranked by percentage of their electricity derived from renewable fuels
Solar includes only utility-scale solar



Duck curve

The typical graph of peak solar power availability (daytime) and demand (nighttime).



Insolation

The fraction of the sun's radiant energy that reaches the Earth. It's tiny, which is good, because the sun produces, in five-billionths of a second, what earthlings produce in a year.

Megafactory

Term coined in 2014 for factories making batteries with a combined capacity of 1 gigawatt-hour or more per year.

Where Texas would rank globally in installed wind capacity if it were a country

SOURCES: U.S. ENERGY INFORMATION ADMINISTRATION; BLOOMBERG NEW ENERGY FINANCE; BUREAU OF LABOR STATISTICS; AMERICAN WIND ENERGY ASSOCIATION; THE SOLAR FOUNDATION; TESLA.COM; DAVID FERRIS,E&E NEWS; EIA WITH CLEAN EDGE ANALYSIS

Wind farms like the Spinning Spur 3, which powers Georgetown, have replaced prairie-dog towns as the dominant feature of the Texas Panhandle.

SOLAR AND WIND POWER ARE BECOMING SO CHEAP, "I CAN'T EVEN TELL YOU WHAT THE COSTS ARE BECAUSE COSTS ARE DROPPING SO RAPIDLY," AN ANALYST SAYS.

R.F.D.," and it does have a town square with a courthouse, a coffee shop where you're bound to run into people you know and a swimming hole. But it also has Southwestern University, and in 2010 university officials, following a student initiative, told the city council they wanted their electricity to come from renewable sources. The city had already set a goal of getting 30 percent of its power that way, but now, Ross and his colleagues saw their opportunity.

Taken together, the generation and distribution of electric power in the United States is an astonishingly complex undertaking. Utilities may generate their own power or buy it from other utilities; that power travels over a grid of transformers and high- and low-voltage lines to your house. Ownership of utilities varies from nonprofits to cooperatives to for-profits. Federal regulators ultimately oversee the grid. Amazingly, when you flip a switch, electricity is there.

In Texas, the top energy sources had long been coal, natural gas and nuclear. But, perhaps surprisingly, the Lone Star State also leads the nation in wind power; capacity doubled between 2010 and 2017, surpassing nuclear and coal and now accounting for nearly a quarter of all the wind energy in the United States. Solar production has been increasing, too. By the end of last year, Texas ranked ninth in the nation on that front.

Which is to say that Ross and his co-workers had options. And the city was free to take advantage of them because of a rather unusual arrangement: Georgetown itself owns the utility company that serves the city. So officials there, unlike those in most cities, were free to negotiate with suppliers. When they learned that rates for wind power could be guaranteed for 20 years and solar for 25 years, but natural gas for only seven years, the choice, Ross says, was a "no-brainer."

In 2016, the city bought its way out of a contract providing energy derived from fossil fuels and arranged to get its power from a 97-unit windfarm in Adrian, Texas, about 500 miles away in the Texas Panhandle. Georgetown doesn't own the farm, but its agreement allowed the owners to get the financing to build it. This spring, Georgetown is adding power from a 154-megawatt solar farm being built by NRG Energy in Fort Stockton, 340 miles to the west of the city.

Even with plans to grow as much as 80 percent over the next five years, the city expects to have plenty of energy from these renewable sources. (To be sure, about 2 percent of the time, the Georgetown utility draws electricity derived from fossil fuels. Ross says the city more than compensates at other times by selling excess renewable energy back to the grid—at a profit.)

Other cities won't have it so easy. Take Atlanta. Residents buy energy from Georgia Power, which is owned by investors. As things stand, Atlantans have no control over how their power is generated, though that may change. In 2019, Georgia Power, by state law, has to update its energy plan. Ted Terry, director of the Georgia chapter of the Sierra Club, says the nonprofit is working with Atlanta officials to incorpo-

"Brewed with Texas wind and Texas water by Texas people," is one motto of the Rentsch Brewery, a local "supporter of the beer garden life."

According to U.S. census figures, Georgetown is the nation's fifth fastest-growing city with 50,000 residents or more, its growth fueled in part by local businesses like the 600 Degrees Pizzeria and Drafthouse.

rate renewables, primarily solar, into the state's plan.

Developing such energy sources on a scale that can power a metro area with 5.8 million people, as in Atlanta, or 7.68 million in the San Francisco Bay Area, or 3.3 million in San Diego, will prove challenging. But it doesn't seem impossible. In 2015, California set a goal of deriving 50 percent of its energy from renewable sources by 2030. Its three investor-owned utilities—Pacific Gas & Electric, Southern California Edison and San Diego Gas & Electric—are poised to achieve that goal just two years from now, or ten years early.

Al Gore says the reason is innovation. "The cost-reduction curve that came to technologies like computers, smartphones and flat-panel televisions has come to solar energy, wind energy and battery storage," he says. "I remember being startled decades ago when people first started to explain to me that the cost of computing was being cut in half every 18 to 24 months. And now this dramatic economic change has begun to utterly transform the electricity markets."

Adam Schultz, a senior policy analyst for the Oregon Department of Energy, says he's more encouraged than ever about the prospects for renewables. Because the Pacific Northwest features large-scale hydropower plants built as part of the New Deal, energy already tends to be less expensive there than the U.S. average. But solar and wind power have "gotten cheaper over the last couple years to the point that I can't even tell you what the costs are because costs have been dropping so rapidly," Schultz says. "We have enough sunshine," he says (presumably referring to the eastern part of the state), "so it's just a matter of time."

Because one obstacle to adopting wind and solar power is reliability—what happens on calm, cloudy days?—recent improvements in energy-storage technology, a.k.a. batteries, are helping accelerate adoption of renewables. Last May, for example, Tucson Electric Power signed a deal for solar energy with storage, which can mitigate (if not entirely resolve) concerns about how to provide power on gray days. The storage upped the energy cost by $15 per megawatt hour. By the end of the year, the Public Service Company of Colorado had been quoted a storage fee that increased the cost of a megawatt hour by only $3

On the campus of Southwestern University (where students rehearsed *A Funny Thing Happened on the Way to the Forum*), environmentally minded students and faculty like to say, "Sustainability begins with 'SU.'"

to $7, a drop of more than 50 percent. In a landmark achievement, Tesla installed the world's largest lithium-ion battery in South Australia last December, to store wind-generated power. But by then Hyundai Electric was at work in the South Korean metropolis of Ulsan on a battery that was 50 percent bigger.

I ask Ross if he worries about what'll happen to his city's power supply if it clouds up over Fort Stockton. He chuckles. "In West Texas, cloudy?" he says. "Really?"

IN 2015, ROSS WROTE AN OP-ED for *Time* magazine about his city's planned transition to renewables. "A town in the middle of a state that recently sported oil derricks on its license plates may not be where you'd expect to see leaders move to clean solar and wind generation," he wrote. Lest readers get the wrong idea, he felt compelled to explain: "No, environmental zealots have not taken over City Council."

A little over a year later, Al Gore, one of the nation's prouder enviromental zealots, showed up in Georgetown with a film crew to interview Ross for *An Inconvenient Sequel*. In the film, when a reporter asks the former vice president whether Georgetown is a trailblazer for cities of similar size, he says, "Definitely."

I ask Gore about the lessons he takes from Georgetown. "I think it's important to pay attention to a CPA who becomes a mayor and takes an objective look at how he can save money for the citizens of his community, even if it means ignoring ideological presuppositions about fossil energy. Especially when the mayor in question is in the heart of oil and gas country."

Ross is now an energy celebrity, sitting on conference panels and lending Georgetown's cachet to environmental-film screenings. And it isn't only conservatives who buttonhole him. As if to prove the adage that no good deed goes unpunished, he also hears from people who worry about the impact of renewables. "They'll come up to me and say with a straight face, 'You know what? Those windmills are killing birds,' " Ross says. " 'Oh, really? I didn't know that was a big interest of yours, but you know what the number-one killer of birds is in this country? Domestic house cats. Kill about four billion birds a year. You know what the number-two killer of birds is? Buildings they fly into. So you're suggesting that we outlaw house cats and buildings?' They go, 'That's not exactly what I meant.'" ◆

Health | EXCLUSIVE

Chicago Doctor Invents Affordable Hearing Aid

New nearly invisible hearing aid breaks price barrier - Under $200

Reported by J. Page

CHICAGO: A local board-certified Ear, Nose, and Throat (ENT) physician, has shaken up the hearing aid industry with the invention of a medical-grade, affordable hearing aid. ***This revolutionary hearing aid is designed to help millions of people with hearing loss who cannot afford—or do not wish to pay—the much higher cost of traditional hearing aids.***

> **"Perhaps the best quality-to-price ratio in the hearing aid industry"**
> **– Dr. Babu, Board-Certified ENT Physician**

The doctor knew untreated hearing loss could lead to depression, social isolation, anxiety, and symptoms consistent with Alzheimer's disease. **He didn't know why hearing aids were so expensive when the prices on so many consumer electronics like TVs, DVD players, cell phones, and digital cameras had fallen.**

Since Medicare and most private insurance plans do not cover the costs of hearing aids, which can cost between $2,000-$6,000 for a pair, many of the doctor's patients could not afford the expense. The doctor's goal was to find a solution that would help with the most common types of hearing loss at an affordable price, similar to the **"one-size-fits-most" reading glasses** available at drug stores. He evaluated numerous hearing devices and sound amplifiers, including those seen on television. Without fail, those were found to amplify bass/low frequencies (below 1000 Hz) and were not effective amplifying the frequencies related to the human voice.

- **Designed by a Board-Certified Ear, Nose, and Throat (ENT) Doctor**
- **Doctor-Recommended, Audiologist-Tested**
- **★★★★★Top Rated Hearing Aid Online— Over 250,000 Satisfied Customers**
- **Save Up To 90%**
- **FDA-Registered**
- **Free Shipping Available**
- **Batteries Included! Comes Ready To Use**
- **100% Money Back Guarantee**

Inspiration from a Surprising Source

The doctor's inspiration to defeat the powers-that-be that kept inexpensive hearing aids out of the hands of the public actually came from a cell phone he had just purchased. **"I felt that if someone could devise a smart phone for about $700 that could do all sorts of things, I could create a hearing aid at an affordable price."**

Affordable Hearing Aid-Superb Performance

The high cost of hearing aids is a result of layers of middlemen and expensive unnecessary features. The doctor concluded that it would be possible to develop a medical-grade hearing aid without sacrificing the quality of components. The result is the **MDHearingAid®** starting at $199. **It has been declared to be the best low-cost hearing aid that amplifies the range of sounds associated with the human voice without overly amplifying background noise.**

Tested by Leading Doctors and Audiologists

The **MDHearingAid** line of aids has been rigorously tested by leading ENT physicians and audiologists who have unanimously agreed that the **sound quality and output in many cases exceeds more expensive hearing aids.**

DOCTORS AND PATIENTS AGREE:

"BEST QUALITY SOUND"
"LOWEST AFFORDABLE PRICE"

"I have been wearing hearing aids for over 25 years and these are the best Behind-the-Ear aids I have tried. ***Their sound quality rivals that of my $3,000 custom pair of Phonak® Xtra digital ITE."*** —Gerald L.

"I have a $2,000 ReSound® Live hearing aid in my left ear and the MDHearingAid® in my right ear. ***I am not able to notice a significant difference in sound quality between the two hearing aids."***
—Dr. May, ENT physician

"They work so great, my mother says she hasn't heard this well in years, even with her $2,000 digital! ***It was so great to see the joy on her face. She is 90 years young again."*** —Al P.

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Silicon Valley

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help those people do certain tasks. So you would install an app so that you click on the potato, and then your Waldo takes over and does it for you automatically, really fast, right? So you would have all these application makers making little things that can make someone's job easier, and then eventually you get to a point where you're not just controlling one of these Waldos, you will be controlling maybe 3 or 10 or 100 of these simultaneously, and you're more managing these Waldos now, not controlling them individually. Does that make sense? So you've got this huge scaling effect.

CLARK: Yeah, I don't get excited about the virtual reality stuff, the car driving and robotics and stuff like that. It's just going to happen. The parts that really get my juices going are the human-computer interface, through the nervous system, and biology transformation. If I was a young man just getting a PhD, I would definitely do biology, because I think that's where it's going. A biologist armed with all this knowledge of computer science and technology can make a huge impact on humanity.

ADELE GOLDBERG *former manager of the Learning Research Group at Xerox PARC*: If you were to predict the future based on seeing what is in the labs today and extrapolate, you would believe synthetic biology is the future, not electronics.

HERTZFELD: Because the idea of bio being the next frontier is based on the silicon, really. There's about one hundred billion neurons estimated in most people's heads, and the world knew that 30 years ago and I remember thinking, "Boy, a hundred billion, that's enormous!" And now I think, "A hundred billion? Hey, that's not so much!" Right? . . . It's just that Moore's law has gotten us to the point we're up to dealing with the biological scale of complexity.

ALVY RAY SMITH *computer-graphics pioneer and co-founder of Pixar*: Moore's law means one order of magnitude every five years—that's the way I define it. And so what do you do with another two to three orders of magnitude increase in Moore's law? We humans can't answer that question. We don't know. An order of magnitude is sort of a natural barrier. Or another way to say it is, if you've got just enough vision to go beyond the order of magnitude, you would probably become a billionaire.

CLARK: I think that connecting humans to computers, having that interface, is increasingly going to be possible with a helmet that's measuring neurological signals from the brain and using that to control things. I'm pretty sure that 20 years from now we're going to be well into getting the human-computer interface wrapped around a direct kind of brain-fed interface.

HASSAN: We're going to tap right into the optic nerve, and insert things that you don't see, but your brain doesn't know that you don't see them. We're just going to insert it right into your optic nerve. We really don't understand how memory works and stuff like that, but we understand somewhat how the optic nerve works, because it's just a cable going back to your brain, and, you know, we know in theory how to insert things into it, so it's just a bunch of engineering work to make that happen.

CLARK: And, as time goes on, I think we'll get more and more refined at being able to map and infer and project those signals, on the cortex, on the brain, and I feel as certain about that as I feel about anything.

LARRY PAGE *co-founder of Google*: Eventually we'll have the implant, where if you think about a fact, it will just tell you the answer.

HASSAN: It's maybe 20 years away. I mean it depends on how well the market takes up MR, mixed reality. If it really loves it, then it's going to be sooner, so if it's slow to pick up, then it's going to be longer. But I think eventually it's going to be there.

CLARK: We will for sure be controlling computers with thoughts, and I think increasingly we're going to have kind of hybrid systems that are kind of biological- and computer-like, and they're going to be there to make humans more effective at whatever.

KELLY: Then I would say that in 30 years people will be beginning to get used to the idea that you can have artificial consciousness. . . . Yet we're already there in a sense; it's already begun and we don't even recognize it. The first part of it has already been completed, the sense that three billion people are online, so it has begun.

HASSAN: If any one of the technologies that I know of that are being developed right now in Silicon Valley does really well, the world is going to be an amazing place. But the really amazing thing that I think is probably going to happen is that they all are going to do well. So, I'm a superoptimist.

KELLY: What we're really making here is something that is humanity plus: It's us, plus the machines, plus the planet. ◆

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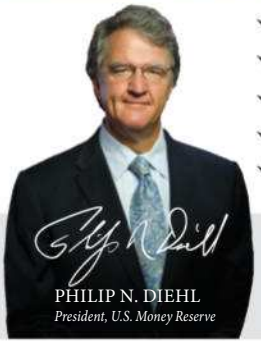
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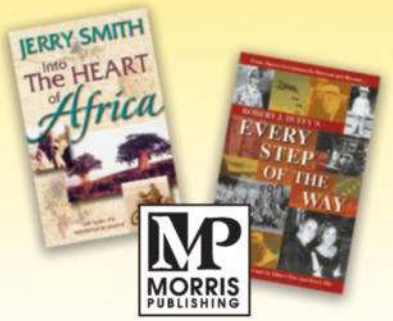

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To researchers, this is far more than just an appearance issue. It could be even more important to Americans who mistakenly believe that small amounts of exercise can radically change their bodies.

According to Dr. Todd Miller, professor in the Department of Exercise Science at George Washington University, "People don't understand that it is very difficult to

exercise enough to lose weight. If that is why you are doing it, you are going to fail." So a way to battle belly fat could be the breakthrough the health community has been waiting for. McClain feels the technique works best for people over 30, particularly those who may be experiencing excessive fatigue, weaker bodies, and even foggy thinking.

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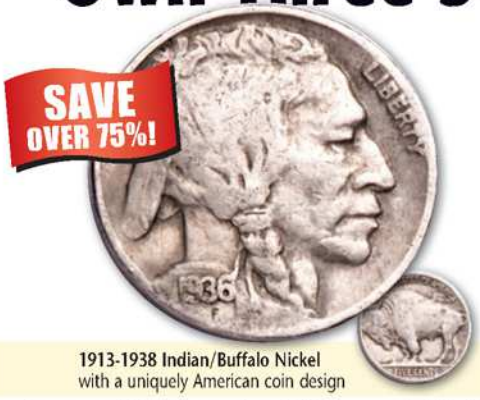

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Bitcoin

CONTINUED FROM PAGE 15

give someone $4 worth of New Hampshire money for it, because, well, to truly redeem that bill for gold or coins you'd need to travel to Pennsylvania. The farther the provenance of the bill, the less it might be worth.

"As crazy as this sounds, this was normal for Americans," says Steven Mihm, associate professor of history at the University of Georgia and author of *A Nation of Counterfeiters*. In a very real way, Americans thought daily about the philosophy of currency—what makes a bill worth something?—in a way that few modern Americans do. It makes them far more similar to those digital pioneers today, pondering the possible value of their obscure alt-coins.

ONE THING that made it even harder to trust currency was the rampant counterfeiting. Creating fake money was so easy—and so profitable—that all the best engravers worked for the criminals. Newspapers would print columns warning readers about the latest forgeries. Yet Americans mostly shrugged and used the counterfeit bills. After all, so long as the person you were doing business with was willing to take the bill—well, why not? Fakes might be the only currency available. Keeping business moving along briskly was more important.

"Using counterfeits was a typical thing in merchants, and bars. Especially in a bar! You get a counterfeit bill and you put it back in circulation with the next inebriated customer," says Mihm. Rather than copy existing bills, some counterfeiters would simply create their own, from an imaginary bank in a far-off U.S. state, and put it into circulation. Because how was anyone going to know that bank didn't exist?

Banks themselves caused trouble. A nefarious banker would print bills of credit, sell them, then close up shop and steal all the wealth: "wildcatting." A rumor that a healthy bank was in trouble would produce a "bank run"—where customers rushed to withdraw all their money in hard, real, metal coins, so many at once that the bank wouldn't actually have the coins on hand. A bank run could de-

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stroy a local economy by making the local currency worthless. Banks, and bankers, thus became hated loci of power.

Yet the biggest currency crisis was still to come: the Civil War. To pay for the war, each side printed fantastic amounts of dough. Up North, the Union minted "greenbacks." One cartoon mocked politicians of the time, with a printer cranking out bills while complaining: "These are the greediest fellows I ever saw . . . With all my exertions I cant [sic] satisfy their pocket, though I keep the Mill going day and night."

When the North won the war, the greenback retained a decent amount of value. But the South under Jefferson Davis had printed a ton of its own currency—the "grayback"—and when it lost the war, the bills became instantly worthless. White Southerners were thus economically ruined not only by the freeing of their previously unpaid-for source of labor—the slaves—but by the collapse of their currency.

In the 1860s, the federal government passed laws establishing a national banking system. They also established the Secret Service—not to protect the president, but to fight counterfeiters. And by the late 19th century, you could wander the nation spending the American dollar more or less confidently in any state.

BITCOIN—and today's other cryptocurrencies—solve old problems of currency and create new limits on how it's used. They cannot easily be counterfeited. The "blockchain"—that accounting of every transaction, copied over and over again in thousands of computers worldwide—makes falsifying a transaction unbelievably impractical. Many cryptocurrencies are also created to have a finite number of coins, so they can't be devalued, producing runaway inflation. (The code for Bitcoin allows for only 21 million to be made.) So no government could pay for its military ventures by arbitrarily minting more Bitcoin.

This is precisely what the libertarian fans of the coin intended: to create a currency outside government control. When Satoshi Nakamoto, the secretive, pseudonymous creator of Bitcoin released it in 2009, he wrote an essay savagely critiquing the way politicians

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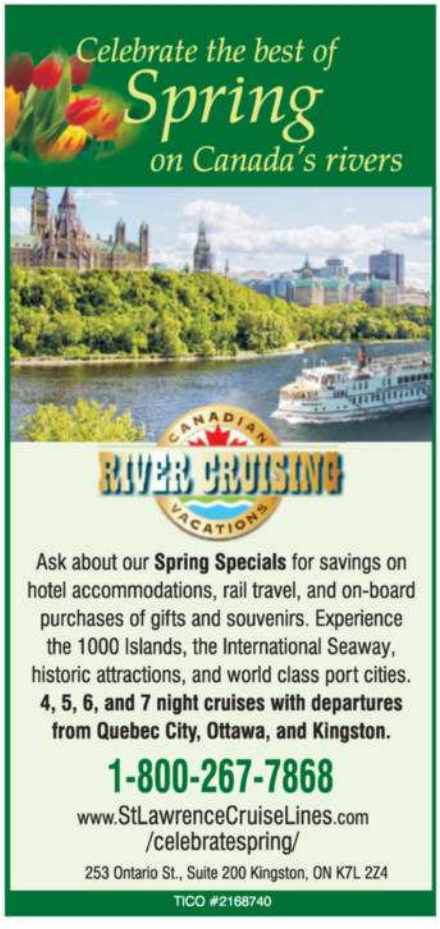

SMITHSONIAN; April 2018; Volume 49, Number 1. *Smithsonian* (ISSN 0037-7333) is published monthly (except for a January/February issue and a July/August issue) by Smithsonian Enterprises, 600 Maryland Ave. S.W., Suite 6001, Washington, D.C. 20024. Periodical postage paid at Washington, D.C. and additional mailing offices.
POSTMASTER: send address changes to Smithsonian Customer Service, P.O. Box 62170, Tampa, FL 33662-2170. Printed in the USA. Canadian Publication Agreement No. 40043911. Canadian return address: Asendia USA, PO Box 1051, Fort Erie, ON L2A 6C7.

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print money: "The central bank must be trusted not to debase the currency, but the history of fiat currencies is full of breaches of that trust."

Still, observers aren't sure a currency can work when it's backed only by the faith of people participating in it. "Historically, currencies require either that it's based in something real, like gold, or it's based in power, the power of the state," as Weatherford says. If for some reason the community of people who believe in Bitcoin were to falter, its value could dissolve overnight.

Some cryptocurrency pioneers think alt-coins are thus more like penny stocks—ones that get talked up by shysters to lure in naive investors, who get fleeced. "I want a worse word than 'speculation,'" says Billy Markus, a programmer who created a joke alt-coin called "Dogecoin," only to watch in horror as hucksters began actively bidding it up. "It's like gambling, but gambling with a very standard kind of predictable human emotions."

Mihm thinks the rush toward Bitcoin illustrates that the mainstream ultimately agrees, in some way, with the libertarians and anarchists of alt-coins. People don't trust banks and governments. "The cryptocurrencies are an interesting canary in the coal mine, showing a deeper anxiety about the future of government-issued currencies," he says.

On the other hand, it's possible that mainstream finance may domesticate the various alt-coins—by adopting them, and turning them into instruments of regular government-controlled economies. As Cameron Winklevoss points out, major banks and investment houses are creating their own cryptocurrencies, or setting up "exchanges" that let people trade cryptocurrencies. (He and his twin set up one such exchange themselves, Gemini.) "It's playing out, it's happening," he notes. "All the major financial institutions have working groups looking at the tech." He likens blockchain technology to the early days of the internet. "People thought, why do I need this? Then a few years later they're like, I can't live without my iPhone, without my Google, without my Netflix."

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Q: How come I see fireflies in New York, Illinois, Iowa and all through the South, but not in the West?

— **Todd Schmidt** | Chico, California

WELL, you can see fireflies in the West, but you have to look a lot harder, says Marc Branham, a research associate at the National Museum of Natural History and an associate professor of entomology at the University of Florida. There's kind of a firefly Continental Divide, and it has to do with flashing behavior among adults. Among Eastern species, males flash while they're in flight to attract females; those species don't live farther west than Kansas, except for a few isolated populations. Out West, it's the adult females that glow, but only while they're on the ground, and very faintly—so faintly their glow is hardly detectable even to a human eye fully adapted to the dark. And few people venture out without a flashlight or other light on.

Submit your queries at **Smithsonian.com/ask**

Q: Of the 120,000 Japanese-Americans who were interned for security reasons during World War II, how many were convicted of spying against the United States?

— **Ted Elswicke** | Fernley, Nevada

NONE, DESPITE AGGRESSIVE investigating. The U.S. government did convict ten people of spying for Japan, and they were all Caucasian, says Adriel Luis, curator at the Smithsonian Asian Pacific American Center. In 1988, President Ronald Reagan signed the Civil Liberties Act, which formally apologized for the internment and compensated each surviving internee with $20,000. Still, the Supreme Court has upheld the government's right to hold citizens without trial or hearing in wartime.

Q: Is the speed of light finite? Is it limited to 186,000 miles per second?

— **Chris Gibbons** | Evergreen, Colorado

YES, ON BOTH COUNTS, says Avi Loeb, a theorist at the Harvard-Smithsonian Center for Astrophysics. In 1905, Albert Einstein realized that the speed of light is a constant of nature. This serves as the basis of his special theory of relativity, which has been tested and confirmed by many scientists. It states that no material object can move faster than that speed and that the speed doesn't change depending on your frame of reference. If you near the speed of light, time does slow down, so if you boarded a superfast spacecraft you would age more slowly than your relatives on Earth.

Q: Did Phyllis Diller really donate her jokes to the Smithsonian?

— **Kate Patrick** | Frederick, Maryland

YES, SHE DID, IN 2003. Diller offered to make a gift to the institution after hearing that the National Museum of American History had displayed Archie Bunker's chair. ("Even if I end up in the zoo or with the mammals, I will be honored," she wrote to Smithsonian Secretary Lawrence M. Small.) She ended up giving her entire gag file—51 drawers containing 52,569 jokes, each typed on an index card, says Hanna BredenbeckCorp, a project assistant at the museum. The comic, who died in 2012, wrote most of them, bought some from joke writers and accepted some from fans. (Sample: "When I first got into this business I thought a punch line was organized drinking.") BredenbeckCorp has digitized the jokes; you can see some of them at smithsonianmag.com/jokefile. ◆

Text by ***Anna Diamond***

Illustration by **Ariel Davis**






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