Stories of People Who Are Racing to Save Us

Humanity is facing thorny problems on all fronts. These folks are working to solve them—and trying to avoid the unintended consequences this time.

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Climate change. Flawed algorithms. Deadly diseases. Tech monopolies. We are facing many existential challenges that need to be tackled head-on before it's too late. Many of these problems are of our own making, consequences of our relentless push for progress. Fortunately, there are lots of people who are racing to save us from ourselves—progress we can definitely get behind. Whether it's arming the immune system's T-cells to precisely target tumors, developing eco-friendly alternatives to livestock-industry meat, or monitoring the internet's hell sites to sniff out trouble, the 25 people and groups here offer real hope that we can fix the mistakes of the past and still have a chance for a future we can survive. —*The Editors*

Join us for the return of the WIRED25 Festival, lively stage chats and workshops with luminaries and icons, from Chris Evans and N. K. Jemisin to Stewart Butterfield and NSA cybersecurity head Anne Neuberger.

MEDICINE

Arming the Immune System to Kill Cancer—and More

Wendell Lim

SYNTHETIC BIOLOGIST / UC San Francisco

When Wendell Lim booted up his biophysical chemistry lab at UC San Francisco in 1996, he had no ambition to hack the human immune system. He was focused on more basic questions, like decoding the underlying logic of biology. Lim, who nearly majored in art at Harvard, sought answers through genetic engineering. For years he tinkered with yeast, inserting code into its DNA to make it do things never seen in nature.

Then, in 2010, he met a University of Pennsylvania oncologist named Carl June who was developing a cancer treatment called CAR-T. It involves genetically engineering T cells—the assassins of the immune system—to create a clone army trained to find and destroy a patient's unique cancer. In 2011, June published CAR-T's first breakthrough success, which set off a tsunami of clinical trials, leading to (so far) two FDA-approved treatments. But June and others were worried. A clone army can also be deadly—it's hard to make T cells that kill only cancer, with no collateral damage. Hearing this, Lim realized the tools he'd been tinkering with could make CAR-T safer and more reliable.

Since 2015, Lim's lab has been making more finely tuned T cells. One requires a drug to trigger its kill mode. Others use multiple molecular markers to identify cancer, like two-factor authentication. First-gen CAR-T therapies rely on a single lock-and-key switch, Lim notes, but a tumor is a complex, mutating environment. That's why he's designing cells to read patterns of molecules, a bit like how facial recognition algorithms analyze faces. He's also creating T cells that attack only when there's a critical mass of tumor-specific molecules present, and a version that intercepts signals between tumor cells to stage assaults on the whole network.

Lim expects some of his early T cell designs to be tested in humans within

two years. But he's already looking beyond cancer, to hacking the whole immune system: Healing wounds, halting degeneration, preventing autoimmunity—all of it could be guided by designer cells. "The culture now is that CAR-T is just a big toxin attached to an antibody," Lim says. "The idea that immune cells are programmable computational devices that can do many things is pretty far away, but I'm hopeful we change that."
—*Megan Molteni*

ARTIFICIAL INTELLIGENCE

Calling Out Bias Hidden in Facial-Recognition Technology

Joy Buolamwini

FOUNDER / Algorithmic Justice League

In 2015, MIT Media Lab master's student Joy Buolamwini gazed, puzzled, into her webcam. She was working on an art piece to project digital masks on faces, but her own was invisible to the off-the-shelf face-tracking software she was using. She scrawled a face on her hand in marker. Face detected. Hmm. She covered her dark skin with a white mask left over from Halloween. Face detected. Oh.

Buolamwini had come to MIT to explore how people could use technology for social change. The algorithm that couldn't see her face set her on a new path: exploring how tech could be misused and abused. When she learned how [facial recognition](#) is used in law enforcement, where error-prone algorithms could have grave consequences, she says, "that's when it became urgent."

Buolamwini, now working on a PhD at MIT, is among those pressing companies and governments to be more cautious in

their embrace of AI. Her work has revealed biases in facial-analysis algorithms from Amazon, IBM, and Microsoft. She showed that the services frequently saw women with dark skin as men but made few errors on men with light skin. (All three companies say their tech is now more accurate.)

Buolamwini believes that people developing AI tech should check their inventions for bias and other harms before launch, not rely on Good Samaritans like her to audit them later. She spearheaded the Safe Face Pledge with Georgetown Law—a call for companies to agree to take steps aimed at mitigating the harms of facial analysis. She's also pushing for a moratorium on police and government use of facial recognition to allow time for debate and possibly the creation of regulations. "We need public deliberation," Buolamwini says. Her own deliberation takes place in scientific papers, congressional testimony, and spoken word poetry. "It's our stories that lead to change," she says. —*Tom Simonite*

FILTER BUBBLES

Pushing Big Tech to Clean Up Its Algorithms

Guillaume Chaslot

FOUNDER / AlgoTransparency

I used to work at Google, but I had a more positive impact on it after I left.

When I started at the company in 2010, I had recently completed a PhD in artificial intelligence, and I joined a team working on new algorithms to recommend YouTube videos. Our work centered on increasing a single number—the amount of time people spent watching videos. That was seen as the way to compete with Facebook and gain audience from TV. In my experience, every other idea or creative thought was dismissed.

Our team had a handful of people, but I'd say our recommendations increased watch time by millions of hours. They were designed to suggest videos that a person was likely to watch, based largely on their past activity on the service. But we had no idea what people were watching. We assumed that because watch time was moving in a positive direction, the impact on the audience was also positive.

Still, I began to worry that the system we built could trap people inside filter bubbles, pushing them to experience the same type of content over and over. I helped prototype new ways to offer recommendations that would diversify what people saw, but those systems were never implemented. I was eventually fired for performance issues.

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Illustration: Mike Perry

After leaving Google I joined a startup, then did some consulting before going to a nonprofit. But I kept worrying about the power of YouTube's recommendations. I decided to test them with a robot—a piece of software that watches lots of videos and follows recommendations.

The 2016 presidential election was approaching, so I directed the robot to watch videos about Donald Trump and Hillary Clinton. What I discovered was frightening. My analysis showed YouTube's recommendation system was helping videos promoting political conspiracy theories—like those from right-wing radio host Alex Jones—to get millions of views.

I was shocked, and launched a website called AlgoTransparency that shows live data on what my robot discovers about YouTube recommendations. Journalists started writing about what I found, and YouTube finally acted. The company began adding Wikipedia links below conspiracy theory videos to help people recognize them. This January, the company changed its recommendation algorithms to limit the spread of conspiracy theories. My data suggests this could reduce the number of times the site recommends conspiracy videos each year by the billions. Recommendations are

responsible for more than 70 percent of time spent on YouTube, so the effect could be dramatic.

I'm building a browser extension that will warn you about the algorithms trying to manipulate you as you browse the web ... It might say, "This algorithm is made to make you binge-watch, not to recommend things that are true."

My experience shows that we can hold giant technology companies to account if we have the right tools. I'm now upgrading AlgoTransparency to display richer data, and I'm building a browser extension that will warn you about the algorithms trying to manipulate you as you browse the web. Its advice will be a bit like health ratings on food—some of the things you enjoy you shouldn't eat every day. For YouTube's recommendations, it might say, "This algorithm is made to make you binge-watch, not to recommend things that are true."

Longer term, I hope work like mine can allow new technology companies to emerge that make ethics their first priority. Facebook and Google claim to have reformed, but large companies won't change their business models and values. Users don't realize how much power they would have if they were paying for a service. Signal, a free messaging app, enables you to communicate with anybody, similar to Facebook's WhatsApp, but doesn't rely on ad revenue. A complex service like Facebook could be run in its users' interest, without ads, if people paid a small amount, say a dollar a month. If consumers can be helped to see the problems with existing, ad-driven services, they may support companies that operate differently. *—As told to Tom Simonite*

(YouTube questions the accuracy of the AlgoTransparency tool and says

its service now optimizes for user satisfaction and information quality in addition to watch time.)

CYBERSECURITY

Protecting the Rest of Us From Hackers and Spies

Eva Galperin

HEAD OF THREAT LAB / Electronic Frontier Foundation

Eva Galperin divides the targets of state-sponsored hackers into two categories: First, there are the corporations, government agencies, and billionaires that can afford to pay expensive cybersecurity consultants, staff 24/7 security operations centers, and hire incident responders after a breach. Then there's everyone else—an underclass of victims who enjoy virtually none of those pricey protections. But now they do, at least, have Eva Galperin.

Earlier this year, Galperin, the head of cybersecurity at the [Electronic Frontier Foundation](#), formed a new and unusual team within the venerable digital rights group. For nearly three decades, the EFF has acted as a kind of geeky nonprofit law firm, fighting to protect online privacy and free expression in court, defending security researchers, and launching lawsuits against everyone from patent trolls to warrantless-wiretap enablers. But Galperin's new initiative, called the Threat Lab, is more like a small, nonprofit cybersecurity consulting firm—a sort of CrowdStrike or FireEye for the little guy.

Galperin and her team focus on protecting the activists, dissidents, lawyers, journalists, and civilians who find themselves in an increasingly lopsided conflict with entities that hack, surveil, and sabotage them—or better yet,

equipping them to protect themselves. "I think that empowering people to confront power is good," she says. "That's how change happens."

In part, Galperin aims to create tools that level the playing field for surveillance victims. In its first months, for instance, the Threat Lab's tiny team of three full-time staffers has been building a device to detect a common form of police surveillance: fake LTE cell towers that trick phones into connecting to them, enabling police to pinpoint the location and track the identities of protesters and other surveillance targets.

The Threat Lab also does detective work to expose perpetrators of state-sponsored surveillance. For years, even before the team's creation, Galperin and fellow EFF researcher Cooper Quintin investigated a hacking operation that planted spyware on the computers of journalists and opposition figures in Kazakhstan. Working with the mobile security firm Lookout, Galperin's team found that some of the same tools—perhaps made by the same for-hire hackers—were being used in a massive campaign to spy on civilian targets in Lebanon. At one point during that investigation, the EFF had a researcher walk the streets of Beirut with a smartphone to find the Wi-Fi network they'd linked with the hackers. The researcher discovered it was emanating from inside the headquarters of the Lebanese General Security Directorate.

> ## *The EFF had a researcher walk the streets of Beirut with a smartphone to find the hackers' Wi-Fi network. It was emanating from inside the headquarters of the Lebanese General Security Directorate.*

Galperin's own obsession is the scourge known as spouseware, or stalkerware: hidden apps installed on a smartphone by someone with

physical access to the device—often a domestic abuser—that let them spy on the phone's owner. Since early 2018, Galperin has offered her services as a kind of first responder, security consultant, and therapist for stalkerware victims.

But Galperin wasn't satisfied with the scale of that hands-on approach. So she began shaming and pressuring the antivirus industry, which has long neglected stalkerware, to take it far more seriously. Several companies have since pledged to catalog and eradicate the apps just as thoroughly as they do traditional malware. "Stalkerware is considered beneath the interest of most security researchers," Galperin says. "Changing norms takes time. But it starts with someone standing up and saying 'This is not OK, this is not acceptable—this is spying.' "

Galperin, who has silvery-violet hair and a cyberpunk aesthetic, got her start as a systems administrator, attending security conferences and being treated, she says, like "some hacker's girlfriend who looks after Solaris boxes." In 2007 she joined the EFF, where her first job was to answer the 50-plus calls and emails that came in every day from people seeking help. The organization had recently filed a lawsuit against AT&T for aiding warrantless NSA spying, and Galperin was flooded with messages from people who had been targeted for surveillance. Her desk became a kind of security crisis hotline.

According to Danny O'Brien, Galperin's former boss at the EFF, the experience gave her a strong sense of the victim's perspective—something that's often overlooked by the cybersecurity research community, which tends to focus more on sexy new hacking techniques than on the people who suffer from their use. "Eva isn't afraid to plot out the consequences of hackers' actions," O'Brien says, "to stare those consequences down until the problem is solved."

She's also good at plotting out, and maximizing, the consequences of her own actions. Galperin says she has no illusions that she or her small team

alone can tip the balance of security for vulnerable people worldwide. But in line with the EFF's longtime tactic of choosing cases that can set legal precedents, she says she chooses projects that promise to have cascading effects, that will force the industry to change its priorities or inspire other researchers. "You figure out the place where you need to push," she says, "not just to help the people you help every day, the individuals, but to change the game. To change the system." —*Andy Greenberg*

INFORMATICS

Chad Rigetti

FOUNDER & CEO / Rigetti Computing

In 2013, Chad Rigetti became aware that the field of quantum computing was entering a kind of adolescence. Sketched out in the 1990s, the technology was supposed to leapfrog conventional computing by tapping into the weird physics of subatomic particles. For years, researchers had been held up by the devilish unreliability of qubits, the devices needed to perform quantum manipulations on data. But now, finally, they were finding new ways to tame them. "It was black magic, and then a framework emerged," Rigetti says. "You could start to see all the pieces coming together." That's when he quit his job at IBM and struck out on his own. Six years later, in labs stocked with steampunky equipment and liquid helium, Rigetti Computing is manufacturing small quantum processors.

The machines on our desks and in our pockets solve problems by flipping bits from 0 to 1, or vice versa. Qubits use the same binary format, but they can also ascend into a third state, called a superposition—neither 0 nor 1 but both simultaneously (well, sort of). Thanks to this trick, a quantum computer can zip through calculations that would trouble a conventional machine. Rigetti's processors are being designed as add-ons: They'll take a regular computer and give it a quantum boost, creating a best-of-both-

worlds hybrid.

Some of Rigetti's customers are already test-driving its hardware over the cloud. Others are exploring software applications. The pharmaceutical giant Merck, for instance, is investigating ways to streamline drug production. NASA is looking to speed up the search for new planets in telescope data. Rigetti's chips aren't consumer gadgets (for one thing, their operating temperature is colder than any natural place in the known universe), but they could still change your life.

Unlike its rivals—Google, IBM, Intel, Microsoft—Rigetti can't count on profits from online ads or workplace software. That's partly why it's pushing the hybrid model, which should be quicker to bring to market than stand-alone quantum computers. As Rigetti sees it, his team benefits from being untethered to older ways of thinking. "We're free from history," he says. —*Tom Simonite*

Three questions for …

Matthew Prince

COFOUNDER & CEO / Cloudflare

1. Recently, [Cloudflare](#) acted under pressure to kick bad actors off its service—the Daily Stormer, then [8chan](#). What concerns you most about tech right now?

The internet is at a crossroads. Most of the globe has followed the model set by the US, where anybody can post online and content is generally available to all. But a lot of the world has lost faith in that model. The alternative is closer to China's. China treats the internet the way the US treats radio stations, where you need a license to put content on it. The bad news is that I think we will move toward that more permissioned model, which constrains innovation.

2. Where's the biggest impact of this shift?

I'm thinking a lot about India. Whatever internet policy India sets is likely to be adopted by the rest of the world. India has the critical mass to do that. It doesn't have the best record in terms of technologies like encryption. But it has the fastest-growing internet user base and some incredibly innovative business models.

3. How do we guard against unintended consequences?

I don't know that there's any perfect answer to that, but I think being more modest is important. Taking smaller steps. Does a situation really require a radically different approach, or can we rely on existing principles?

—Lily Hay Newman

SUSTAINABILITY

Building a Fully Recycled and Recyclable iPhone Supply Chain

Lisa Jackson

VP OF ENVIRONMENT, POLICY, AND SOCIAL INITIATIVES / Apple

In Lisa Jackson's first year at Apple, fresh off a stint as President Obama's administrator of the Environmental Protection Agency, she took over a campaign to transition all company facilities to 100 percent renewable energy. But before Apple hit that goal in April 2018, Jackson rolled out an even more audacious plan: designing an iPhone made entirely from recycled materials.

Since then, Jackson and her team have come up with new methods of recycling aluminum and recovering tin, engineering faster circuits that use

less silicon, and [building robots](#) that can strip down 200 iPhones an hour.

These advances bring Apple closer to what Jackson calls a "moon shot" goal: to make *all* of its products using renewable resources and recycled materials. She and her team began by evaluating each of Apple's production materials for its environmental and social impact, along with the vulnerability of its supply, and identified 14 elements to start with. To date, they've upgraded 11 iPhone models with main logic boards soldered using only recycled tin.

This isn't enough for Greenpeace, which remains fairly unimpressed with the company's efforts. But the environmental group also ranks Apple as greenest among large tech companies for its recycling efforts and its shift to renewable energy. Jackson's fully recycled supply chain is still years away, but according to colleagues, the word *impossible* is not in her lexicon. If that's so, we have a challenge for her: Can she recycle some old headphone jacks into the next-gen iPhone? —*Meghan Herbst*

1. Rare Earths: The Taptic engine—Apple's key component for producing haptic feedback—in the iPhone 11 models uses 100 percent recycled rare-earth metals.

2. Cobalt: A disassembly robot called Daisy extracts cobalt from recycled iPhones. The company is now producing batteries with the reclaimed material.

3. Tin: At least 15 Apple products use 100 percent recycled tin in the solder for their main logic boards and some power adapters.

4. Aluminum: In 2018, Apple developed a process for smelting recycled aluminum that produces a much higher quality finish. The company is also investing in greener smelters, intended to eliminate carbon dioxide emissions.

ACTIVISM

Suing the US Government Over Climate Change

The youth plaintiffs in *Juliana v. United States*

In 1996, the UN's Intergovernmental Panel on Climate Change issued the second in a series of increasingly [dire reports](). More frequent heat waves, floods, droughts, fires, and pest outbreaks were on the way, scientists said. The time to act was now.

KEY: **1**. Nathan Baring **2**. Avery M. **3**. Miko Vergun **4**. Kiran Oommen **5**. Hazel V. **6**. Levi D. **7**. Nick Venner **8**. Isaac V. **9**. Tia Hatton **10**. Jacob Lebel **11**. Vic Barrett **12**. Sahara V. **13**. Xiuhtezcatl Martinez **14**. Alex Loznak **15**. Zealand B. **16**. Journey Zephier **17**. Kelsey Juliana **18**. Sophie Kivlehan **19**. Jaime Butler **20**. Aji Piper **21**. Jayden F.Illustrations based on portraits by Robin Loznak/Our Children's Trust

That same year, in a small forested town in Oregon, Kelsey Cascadia Juliana was born. Her parents, who met at an anti-logging demonstration, named her after the nearby Kelsey Creek and the Cascadia bioregion. They took her to her first environmental protest when she was two months old. Over the next 14 years—as Juliana tasted her first wild huckleberries, peered into her first tidal pool, and first went backpacking in the wilderness with her dad—the climate crisis deepened. US carbon emissions rose by 91 billion tons; the fracking boom got under way. When Juliana was 15, she sued the governor of Oregon, demanding a carbon- reduction plan. (The state supreme court will hear the case later this year.)

By 2015, Juliana had had enough. She'd heard that a local legal nonprofit, Our Children's Trust, was mounting a climate suit against the federal government. Together with 20 other young people, ranging in age from 8 to 19, she joined as a plaintiff. Citing harms such as worsening respiratory illnesses, forced relocation due to water scarcity, and the threat of losing their homes to rising seas, Juliana and her coplaintiffs argue that elected officials have failed to protect their constitutional rights. Their case, which

has survived a number of legal challenges from both the fossil-fuel industry and the Obama and Trump administrations, demands nothing less than a sweeping court order on the scale of *Brown v. Board of Education*—one that will affirm the fundamental right to a stable climate system for all.

"At stake are the lives and safety of these young people," says Julia Olson, the lead attorney in the case. "This is really their last stand."

Juliana, who is now 23, agrees. "I want to be a parent and have a family," she says. "I don't know if I'd be able to do that unless I felt like our leaders did everything they possibly could to ensure a livable future." To lose this case, she adds, "would be a huge blow to myself and to my peers who are still holding on to this belief in democracy and justice." Five of her coplaintiffs weigh in above. —*Saraswati Rathod*

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Tia Hatton, age 22

When Hatton was young, she and her family weren't necessarily convinced by scientists' claims about climate change. But when rising temperatures threatened her beloved pastime as a cross-country skier, Hatton dug into the data. She now has a degree in environmental sciences and works for a land trust in a conservative part of rural Oregon. "This is something that should have been resolved 50 years ago," she says. "It totally pisses me off that our government knew about it."

Avery M., age 14

Avery identifies as a "very big animal person." When she was in kindergarten, she raised $200 for the Snow Leopard Trust. Later she did the same thing for wolves, then salmon. At 9 years old, she testified before her city council in Oregon in support of a climate ordinance. The following year, she signed on to *Juliana v. United States*. "I had no idea what I was getting into," she says. "It's kind of disgusting how slow everything is. We have the world on the line, and it's been four years."

Nathan Baring, age 20

Baring grew up in Fairbanks, Alaska. He worries that the formative experiences of his youth—huddling by a wood stove at 40 below, shoveling himself out of snow—are under threat. "We've had to repair roads almost every year because of permafrost melt," he says. "The Arctic is never going to be the same." Baring's parents are state employees, which means their salaries are tied to oil revenues. As the US works to end its reliance on fossil fuels, he says, it can't "just let these oil towns screw themselves. These are my neighbors."

Kiran Oommen, age 22

Oommen fears for their relatives in hurricane-prone Fort Lauderdale, Florida, and in coastal India, where last year more than 480 people died in flooding and landslides from an exceptionally devastating monsoon season. What scares Oommen most about climate change is its disproportionate effect on marginalized communities. "Having loved ones in these places, it doesn't feel great," they say. "What makes it worse is knowing that it's not just natural changes in the environment; it's human-caused."

Levi D., age 12

Levi is the youngest plaintiff in the case. He grew up on a barrier island on the eastern coast of Florida; each year, he and his mother plant beach grass to shore up the dunes. "Every time I see the street flood outside my house, I think about how fragile our barrier island is," he says. "If sea-level rise continues, that means the island I spent my whole entire life on will eventually go underwater."

GENETICS

Unmasking Precisely How Human Cells Can Malfunction

Jason Buenrostro

RESEARCHER / Harvard

When Jason Buenrostro started graduate school at Stanford, he became captivated by a problem that had long frustrated researchers. At the time, Buenrostro was already something of a prodigy: A child of immigrants without high school diplomas, he had attended a small liberal arts college and then worked in a lab where he helped invent a new tool for diagnosing cancer and other diseases.

Within weeks of his arrival, though, Buenrostro was singularly focused. The human body is made of trillions of cells, nearly all carrying the same DNA. What makes a kidney cell different from a brain cell lies in which set of genes—out of the roughly 25,000 in the human genome—are active, meaning turned on and doing stuff (undergoing methylation, interfacing with RNA, and so on). If you think of each individual gene as a single book in the library of our DNA, active genes are the books that are open and being read—and those determine not only what a cell becomes (part of your ear or part of your heart) but what it does (e.g., make a certain set of proteins that prevent cholesterol from sticking to an artery wall).

The problem, Buenrostro discovered, was that scientists had no way to see into tightly wound regions of DNA (inside a nucleus) to glimpse active, open genes. Even the best technology could get a signal only from comparatively large samples—millions of cells, not all the same kind—and find the average activity. But that's a bit like averaging the behaviors of a cat, a dog, a giraffe, and a shark: How can you tell what's doing what? "You were literally taking chunks of skin or chunks of brain or chunks of heart and then asking, 'What's the heart's genetic activity profile? What's the brain's profile?' " Buenrostro recalls. Because the chunks contained so many different cell types, in other words, it "was pretty meaningless." As a result, researchers were effectively blind not only to the fundamental genetics that made cells different but also to the ways cells can malfunction to cause diseases like leukemia, cystic fibrosis, or diabetes.

Buenrostro changed that. In his first year of grad school, he and two mentors adapted a standard technique for sequencing genes so that it would mark only a cell's open genes, rather than the entire genome. It was like turning on a light in a pitch-black room. Within months, the tool, called ATAC-seq, had taken off.

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"It really opened the door," says University of Chicago geneticist Sebastian Pott, who has since developed a sequencing method similar to Buenrostro's invention. Because Buenrostro's tool was both easy to use and quick—an experiment could be done in half a day—questions that had long been impossible to study suddenly became accessible. One of the most pressing was how different kinds of cells were affected by a specific mutation.

"For years, we've had a lot of information about how genetic variants are associated with certain diseases," Pott noted. The problem was that it was hard to know which variants were associated with which cells—and with what result.

Just recently, for instance, a group of researchers discovered that in the lung, the genetic mutation responsible for cystic fibrosis may affect just a single kind of lung cell: a rare structure known as a pulmonary ionocyte. Simply knowing that could help create a more effective or narrowly targeted drug or gene therapy.

But Buenrostro's invention also sparked more sweeping and fundamental changes, especially in cellular taxonomy. Cells had long been classified based on their location in the body, along with a handful of identifying markers—a bit like fingerprints. But, like fingerprints, it was only possible to match prints already on file, not new ones. Single-cell ATAC-seq made it possible to sort cells according to their genetic activity instead, upending old categories. Not long ago researchers estimated that the body contained roughly 200 cell types; now it's clear there are far more—probably

thousands. (One group recently identified 75 cell types in a tiny piece of tissue in the neocortex alone.) And even seemingly identical cells are turning out to have subtle differences. Buenrostro noted that one cell might be more likely to respond to an infection than another, while others seem to pop into existence only under certain circumstances, like when you have the flu.

Those insights could eventually help refine our understanding of what happens when the body gets out of balance. Pott is currently studying patients with inflammatory bowel diseases such as ulcerative colitis, looking at how the proportion of different cell types changes with illness. Buenrostro, who is now an assistant professor at Harvard, has started using single-cell ATAC-seq to see how different cells contribute to certain cancers, and also to study how changes in a cell's genetic activity could affect its ability to self-repair or regenerate as a body ages.

Last year, he also partnered with the life-science company Bio-Rad to create a radically upgraded version of single-cell ATAC-seq, which researchers can buy as an off-the-shelf kit. "Growing up as a first--generation student, and as an underrepresented minority in particular, you don't really think of yourself as having the chops to be an inventor," Buenrostro tells me. "But I always wanted to work on a technology that could change health care." He shrugs, wryly. "You know, big dreams." —*Jennifer Kahn*

BIOTECH

Engineering DNA to Store the World's Data—Forever

Emily Leproust

CEO / Twist Bioscience

Emily LeProust fished around in her pocket until she found what she was seeking: a stainless steel tube, about the size of a large pill capsule. She set it on the table with a metallic ping. "In this you can put dozens of Google data centers," she says. "If not hundreds."

Leproust's company, Twist Bioscience, makes what goes in that capsule: DNA. Hyperdense, easy to replicate, and stable over millennia, it's close to an ideal archival storage medium. Twist engineers the DNA to represent the data, translating the binary code of machines into the [genetic code](#) of life (for example: 00=A, 01=G, 10=C, 11=T). If you want to read that data, say, two centuries later, you sequence the DNA and translate it back to binary. Silicon Valley is investing in DNA storage to replace the short-lived magnetic tape and flash drives housing much of the world's data. By 2040, researchers estimate humans will generate so much data there won't be enough silicon chips to hold it all. Both Micron and Microsoft are funding DNA storage projects. But perhaps no company is pushing harder than Twist.

Six years ago Twist figured out how to ramp up the process of making bespoke DNA. While many traditional machines make 96 short strands of DNA at a time, Twist's robots can make a million, depositing microscopic drops of DNA's building blocks onto silicon chips. But at $1,000 per megabyte, it's still too costly for storing data at scale.

As of September, Twist was finalizing a two-year contract with the Intelligence Advanced Research Projects Activity, an organization within the Office of the Director of National Intelligence. The objective: to lower the cost of DNA data storage to as little as $100 per gigabyte. Twist's ultimate goal? $100 per terabyte. Leproust says that's at least three years out. "We're at the point in society where we're throwing away stuff because we can't afford to store it," she says. "But if you put it in DNA, then it will last forever." —*Megan Molteni*

Three questions for …

Stewart Butterfield

COFOUNDER & CEO / Slack

1. What is the biggest problem on your mind that needs fixing?

Getting people to work together effectively. This isn't something we can "fix" once and for all, just something we can do better. But it's getting more challenging. As software automates away the repetitive, mindless parts of people's jobs, the work that remains demands more of our intelligence and creativity. That's good, but it also means the work is harder to perform and manage. People might not like update meetings and status reports, but we need to find ways to coordinate. When people aren't aligned, they'll be pushing in different directions—and getting nowhere. Creating a sense of common purpose and shared understanding is what allows the group to move forward. It's what turns groups of individuals into teams. Aligned teams adapt faster to changing conditions, and they do so in a more intelligent and responsive way. As a result, they get more done.

2. With that in mind, what ways to address that problem excite you?

You mean, besides Slack? In all seriousness, the most exciting solutions to this challenge are the ones that meet modern workers where they are—especially with the transition to messaging and mobile. A growing percentage of the workforce is comprised of digital natives. Millennials are already the largest group in the workplace, and they're projected to make up 50 percent of the US workforce by 2020.

3. How does that change how we keep workers moving toward a common goal?

The rise of the tech-savvy worker has a massive influence on the tools we use at work. It raises the bar for how technology is expected to make our working lives better. The best solutions remove the obstacles, remove the impediments, remove the inhibitors that modern workers face—and they do

it in a way that anyone can easily understand. It's the solution you don't know you need, but once you have it, you can't live without it.

—*Maria Streshinsky*

ANTITRUST

Laying the Foundation to Break Up Big Tech

Lina Khan

MAJORITY COUNSEL / The US House Subcommittee on Antitrust, Commercial, and Administrative Law

At a CNN town hall meeting this April, Elizabeth Warren fielded a question from an audience member. The questioner, named Meghan, extolled the convenience of Amazon and then asked Warren—who had recently proposed a plan to cut online platforms down to size—"How is breaking up Big Tech good for me?"

The candidate launched in. "A lot of these giant tech companies, they actually run two businesses," she said: They run a platform that connects buyers and sellers, and they compete on that platform as vendors themselves—while collecting near-omniscient data on their rivals. Warren then described how Amazon might use this intel to quash a hypothetical brand called Pet Pillows after it starts to take off: "I know what we'll do," Warren said, imagining the behemoth's thoughts. "Let's jump in front of Pet Pillows and do 'Amazon Pet Pillows' and move Pet Pillows from the front page." (Amazon disputes this characterization of its business practices.) In the name of fair competition, Warren concluded, Amazon's two businesses had to be split up.

"Elizabeth Warren's Really Simple Case for Breaking Up Big Tech," ran the headline of a story that night on Vox. The article gave Warren props for

being "crystal clear on a topic that often feels abstract." But if Warren has become particularly lucid on the issue of antitrust enforcement, she owes much of that clarity to a millennial from Mamaroneck, New York, named Lina Khan.

In 2017, when she was a 27-year-old law student, Khan wrote a paper for the *Yale Law Journal* called "Amazon's Antitrust Paradox." The 24,000-word article offered a careful anatomy of Amazon's market power and called for a wholesale reassessment of antitrust jurisprudence. For 40-odd years, she noted, US authorities have hewed to the theory that they should only take action against monopolies that harm "consumer welfare"—essentially, ones that raise prices. Amazon, she suggested, had stretched the natural limits of anticompetitive behavior in every sense but that one: "It is as if Bezos charted the company's growth by first drawing a map of antitrust laws, and then devising routes to smoothly bypass them."

Khan's article made her the face of a broad movement to revive trust-busting. "Lina's work gave people something you could point to and say, 'Read that and you'll understand,' " says Barry Lynn, a former employer of Khan's who runs the anti-monopoly Open Markets Institute. "It's a document that has become foundational."

Khan certainly seems to have been foundational for Warren. The two met in 2016, and Warren's thinking has often paralleled Khan's since. Khan's 2017 article discusses the case of a real company called Pillow Pets—which faced much the same dilemma as Warren's beleaguered Pet Pillows. And Khan proposes the same policy response that Warren rattled off on CNN: forcing Amazon "to split up its retail and marketplace operation."

After her article blew up, Khan was dismissively pegged as a leader of a "hipster antitrust" movement, but her next moves were anything but hipsterish. In 2018, she became an adviser to Rohit Chopra, a commissioner at the FTC. And she's now the majority counsel to the House Judiciary's antitrust subcommittee. In September, that subcommittee asked more than

80 companies for accounts of how they'd been harmed by Amazon, Apple, Facebook, and Google. Maybe Pillow Pets is one of them. —*J. Brian Charles*

PRIVACY

Helping People Control—and Profit From—Their Own Data

Dawn Song

COFOUNDER & CEO / Oasis Labs

Lately, "owning" your data has emerged as an ideal state. It's seen as a remedy to the rampant collection, leaks, deals, and hacks that compromise our privacy at every turn, and a way to give ordinary users a piece of the action in a hot market. But there's a problem: Share your data with the companies that can put the information to use and it will slip from your grasp, reshared and copied until its value to you is nil. Guard your data jealously and it's just as worthless—because nobody can do anything with it. "I think most people don't even know that their data can be valuable," says UC Berkeley computer scientist Dawn Song. She wants to change that.

Her startup, Oasis Labs, is built on the idea of differential privacy— cryptographic techniques that allow companies to incorporate data into their algorithms without seeing the individual data points. It's the technique Apple uses to collect information on your iPhone without collecting data on you. Song believes blockchain technology can help to push that idea further, offering a secure home for data that doesn't require trusting any one company with the keys to it. That might open up new models of data ownership.

Take health care. Medical researchers would love to use AI to get a better grip on how to cure diseases. However, the data they need is often trapped in hospital and pharma company servers. But you, as a patient, have access,

and Song's system would enable you to copy your medical data onto the Oasis blockchain. There, researchers could use it to train their AI algorithms, but they couldn't snoop through the information or tie it to your identity. You retain control of your data—and can even put a price on it. —*Gregory Barber*

Three questions for …

N. K. Jemisin

Award-winning sci-fi author

1. What concerns you most right now?

Lack of forward-thinking leadership in key positions of our society. We're facing a climate crisis, and the "progressive" members of our government seem committed to the status quo, while the radical right wing seems nihilistically committed to making things worse. We as a species have the intelligence to resolve this.

2. How can genre fiction help?

Simply by portraying the world and humanity accurately. What we see in real life is that technology is just a tool, which can be used or abused. So as writers and readers, we need to be realistic about our engagement with technology—how quickly we acknowledge its limitations and dangers, how rapidly our laws and systems of access adapt to it, whether it's a good thing for everybody or just for some. Science fiction tends to exalt technology as the solution to all of our problems, but *we* are the solution. The tech will follow.

3. What excites you about the future?

The possibility that we might survive it—and become better people.

—*Jason Kehe*

FARM AID

Diagnosing Crop Disease in the Field to Stop Its Spread

Laura Boykin

COMPUTATIONAL BIOLOGIST / Cassava Virus Action Project

Cassava is an obliging plant. The tuber can be turned into flour, paper, adhesives. It can be steamed, fried, roasted, boiled. Sweet or bitter. In Africa, it feeds more than 500 million people daily. Cassava can endure long periods of drought and abide plenty of rain, making it ideal for a changing climate. But for years, viruses have been decimating the tubers. Cassava is dying.

In 2013, Laura Boykin didn't know much about that. She had studied whiteflies—a vector for cassava viruses—and was head-down at her desk at the University of Western Australia, doing computational work on the evolution of various plants, when she was asked to join a team of East African scientists tackling the problem in their countries.

So off Boykin went to start collecting DNA from cassava. Turns out there were mulitple viruses killing the plants and, with enough computer processing power, she could identify the pathogens. But getting an answer took six months, and the diseases were spreading.

Then, in 2015, a company called Oxford Nanopore Technologies built the MinION, a pocket DNA sequencing device that connects to a small supercomputer for data analytics. Boykin got her hands on one.

Today, in just about three hours, Boykin and team can find their pathogen—and help farmers get virus-resistant strains of cassava to plant after they burn their fields. A year ago, the team found the virus that was killing a Tanzanian farmer's crops; the farmer then shared the information with her village. "When we went back months later, 3,000 people had more food," Boykin says.

The Cassava Virus Action Project is only 30 people in six countries, but Boykin isn't deterred. "When you bring the data closer to the problem," she says, "you solve the problem faster." —*Maria Streshinsky*

SPACEFLIGHT

Flinging Small Satellites Into Orbit on the Cheap

Jonathan Yaney

CEO / SpinLaunch

A tyrant guards the gate to outer space, and that tyrant's name is the rocket equation. It states, quite simply, that the heavier your rocket is, the more fuel you'll need to launch it into orbit. That's a problem, because the more fuel you add, the heavier your rocket gets. No amount of calculus can change this stubborn fact: For every ton of payload your rocket carries, it will have to burn nearly 25 tons of liquid hydrogen and oxygen. Short of disrupting gravity itself, what's a tech ideator to do?

Jonathan Yaney and his colleagues at SpinLaunch, a startup based in Long Beach, California, believe they've found the answer. Their nearly fuel-free system, known as a mass accelerator, will use a giant vacuum-sealed centrifuge to spin a payload to more than 4,000 mph. Once released, the payload will go screaming through the atmosphere, coasting nearly 30 vertical miles before propelling itself the rest of the way to orbit by means of a small rocket. The company already has a working prototype; Yaney calls it

"science fiction stuff."

Eventually, Yaney claims, SpinLaunch will be able to fling several 200-pound payloads into space every day, at a cost of less than half a million dollars each— five or 10 times cheaper than the competition. Human passengers are out of the question; the accelerator would turn their bodies to mush. Even satellites must be specially hardened to survive the ride. But that's a small concession, Yaney argues, when you're talking about putting together, say, a constellation of internet satellites in a matter of days rather than months.

Yaney and his colleagues recently broke ground on a facility at Spaceport America, south of Albuquerque, New Mexico, where they expect to begin flight tests by the end of next year. If all goes well, they may finally break the stranglehold of the rocket equation. *Sic semper tyrannis*! —*Daniel Oberhaus*

1. SpinLaunch's vacuum chamber will be angled upward at 35 to 40 degrees, for an ideal launch trajectory. It takes about an hour to pump all the air from the chamber.

2. The accelerator's electric motor spools up to launch velocity in 90 minutes. At its center is a bearing—large enough for a human to walk through—that reduces friction and vibration.

3. The system's arm, called the tether, reaches a top rotational speed of 450 rpm. By comparison, the centrifuge that NASA uses to stress-test payloads tops out at about 50 rpm.

4. The payload is wrapped in a bullet-shaped "aeroshell," which protects the satellite and the small rocket inside like a "violin in a violin case," Yaney says.

5. A mechanical air lock at the end of the launch tunnel opens milliseconds

before the payload takes flight. SpinLaunch will install sonic baffling to dampen the ear-splitting boom.

ECONOMICS

Lighting the Way to a Moon Shot to Fight Climate Change

Mariana Mazzucato

FOUNDER & DIRECTOR, INSTITUTE FOR INNOVATION AND PUBLIC PURPOSE / University College London

A few years ago, when governments across the globe were responding to the financial crisis by embracing fiscal austerity, Mariana Mazzucato assigned herself an odd accounting task: She began tallying all the public investments that had given rise to the iPhone. The internet, GPS, touchscreens, Siri: All that tech had originally been commissioned by either the Pentagon, the National Science Foundation, or the CIA. So why were today's leaders excoriating government spending?

In 2013, Mazzucato published her findings in *[The Entrepreneurial State](#)*, a book that describes how governments have been a primary investor in innovation. Since then, she's become one of the world's most influential economists, advising leaders at the UN, in the EU, and in the US on how to renew the tradition of the government moon shot—just barely in time for the climate emergency. —*John Gravois*

WIRED: *You're part of a group of economists that's reviving an interest in industrial policy—strategic, state-driven economic development. What's the right way to do that?*

Mariana Mazzucato: To think in terms of missions. This year was the 50th anniversary of the [Apollo 11 mission](#): That required dozens of different

sectors and hundreds of homework problems—and who knows how many attempts to solve those problems failed? There was a willingness to take risks and use government instruments to drive bottom-up experimentation. Right now, the climate emergency is a challenge. It's important to turn it into missions, like building 100 carbon-neutral cities across the US. But as an economist I'm not the one to decide what the mission is; the more we can get different voices at the table, the more resilient these missions will be.

The WIRED Guide to Climate Change

The world is getting warmer, the weather is getting worse. Here's everything you need to know about what humans can do to stop wrecking the planet.

You helped advise Alexandria Ocasio-Cortez in formulating the Green New Deal. Is that "mission-driven" policy?

The idea behind the Green New Deal is you need an economy-wide transformation. But it'll be hard for that to happen without some concrete green missions. My point to her was that you have to reframe your view of government as not just a regulator and market fixer but as an active investor with a portfolio, having to make bets across different sectors. And you have to learn from history.

Procurement policy, for example, was pretty much what allowed Moore's law to happen: Semiconductor chips were bought en masse by the government. If the government doesn't use its purchasing power to create markets, then it's very hard for startups to scale up. In the IT revolution, venture capitalists followed the wave of patient, long-term finance provided by the government. Currently, there's a risk that the big wave that VCs surfed in the IT revolution is not happening in the green revolution. You just have a lot of surfers and no wave.

You argue that, because the government takes big risks when it invests in early innovation, it should also expect to see big upsides from those investments. What would those returns look like?

There are lots of ways you can give the public—literally meaning people—a

return for public investment: In the health sector, where you have $39 billion a year being spent by the NIH, it's ridiculous that you have drug prices set by the pharmaceutical industry. The prices could be made to reflect that public investment, and the patent system should be better governed to prevent pure rent-seeking. Also, you can set conditions that require companies to reinvest profits back into the economy instead of spending trillions to buy back shares of their own stock. To retain its monopoly status, AT&T was forced to reinvest its profits—and that's where Bell Labs came from!

People have called you the world's scariest economist. Why? You seem very nice.

When women economists have something to say, they become scary. Having said that, my other answer is: The situation *is* scary, but we can't confront it with being scared. We have to turn global warming into an opportunity to reimagine our economies.

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DIGITAL ABUSE

Powering Real-Time Research Into Online Cesspools

Alex Stamos

DIRECTOR / Stanford Internet Observatory

As the former cybersecurity chief for both Yahoo and [Facebook](#), Alex Stamos knows something about the power—and pitfalls—of sheer size. Which is why his next act doesn't involve protecting any single company's users. It aims instead to shield even larger online populations. How? By

giving researchers around the world what they need to study the scourge of disinformation, security breaches, and propaganda, particularly on social media. Launched earlier this year and funded with $5 million from Craig Newmark's foundation, the Stanford Internet Observatory, which Stamos leads, hopes to act as a clearinghouse for data about all those abuses—both real-time and historical—from across the web. Rather than spend months wrangling data themselves, social scientists could instead put in a call to Stamos and his team. Plenty of work remains before the project is humming, starting with attracting the full cooperation of giants like Google, Twitter, and his former employers. But if anyone can map the universe of digital woes, it's the guy who has spent his entire career fighting them up close. —*Brian Barrett*

ELECTION SECURITY

Saying 'Enough' to Lousy, Vulnerable Voting Technology

Dana DeBeauvoir

COUNTY CLERK / Travis County, Texas

This country's system for running elections is about as decentralized as its system of local public libraries. When Americans go to cast their ballots in November 2020, they'll file into polling places administered by a sprawling archipelago of more than 10,000 county, town, and precinct authorities. Or, as Dana DeBeauvoir puts it, it'll be "Aunt Sally and Uncle Bob" against the Russians.

DeBeauvoir happens to be one of those local officials herself. For more than 30 years, she's been the Travis County Clerk in Austin, Texas. And for much of that time, she's been caught in a bind: forced to purchase clunky, expensive voting machines from the three big vendors in the cartel-like

election industry, while simultaneously catching hell from concerned computer scientists in Texas for buying woefully insecure technology.

In 2011, DeBeauvoir curtly responded to her critics: Why not come to Austin and help her design a better voting machine? "Anyone can tear down a barn," she says. So a motley squad of cryptographers and engineers descended on Austin to design an impregnable voting system from scratch. They left with a dense white paper and a name: STAR-Vote. Their designs call for encrypting the vote using an application of pure math called homomorphic cryptography. There's also a built-in paper trail and a system of automatic audits designed to ensure an election's accuracy with unprecedented certainty.

The trouble was that DeBeauvoir couldn't find anyone to build it. But then this year, Darpa and Microsoft separately revived aspects of the concept under new names, each aiming to develop a prototype within the next few years. The designs will be open source, opening the way for future companies (or tinkerers) to manufacture cheap, secure systems that liberate officials like DeBeauvoir from the tyranny of high-priced, hidebound, hackable technology. Soon, thanks to her initiative, anyone may be able to build a barn. —*Benjamin Wofford*

FINTECH

Making Change, Step by Step, to 'Increase the GDP of the Internet'

Patrick Collison

COFOUNDER & CEO / Stripe

Patrick Collison, the 31-year-old cofounder and chief executive of Stripe, is an exceedingly careful thinker. In his Twitter bio, he identifies himself as a

"fallibilist," by which he means he likes to probe every system of ideas, looking for its bugs. Collison fits a Silicon Valley archetype: a programming whiz who dropped out of college (MIT) and started a company now worth a stratospheric sum ($35 billion, on paper). But unlike others in his cohort, he speaks in strikingly self-effacing terms. At a conference in May, he described Stripe as "a hard-to-understand and maybe boring company."

Well, fair enough. But let's give it a whirl. There is a piece of plastic in your pocket. Every time you enter the number on it into a website or app and click Buy, money moves from you to the vendor. The process is fast but not instantaneous. The payment travels through a hidden domain of processors and merchant banks, each of which charges fees and requires vendors to do lots of paperwork. For young companies that want to accept payments—especially tech startups, which are Stripe's core clientele—that can be a costly time suck. By using Stripe's software, they essentially outsource the hassle. Stripe acts like an E-ZPass, allowing its clients to skip the tollbooths and charging a flat fee, usually around 3 percent of every transaction.

Collison describes the financial system that his company navigates as a clunky piece of legacy infrastructure that needs to be modernized. But he doesn't rail against it or advocate starting from scratch, as [cryptocurrency](#) enthusiasts do. Stripe employs hundreds of workers to comply with complex rules in many jurisdictions and to monitor for fraud and money laundering. "Just to state the obvious, regulating finance is a good idea," Collison says. "It's people's money." He wants to renovate, not demolish. "We've always been very incremental in our strategy," he says. "We're really not believers in radical disruption or epochal transformation." Strange words in Silicon Valley.

He does believe, however, that incremental change can have epochal consequences. Collison lives in San Francisco now, but he's from Ireland, and he wants Stripe to facilitate global trade. A service called Stripe Atlas allows a company anywhere in the world to incorporate in Delaware, so it

can more easily access the US market and banking system. In Collison's view, these small interventions should add up to fulfill Stripe's mission: "to increase the GDP of the internet."

Last spring I met Collison for lunch at an Indian restaurant in Washington, DC. He is skinny and fair, with strawberry blond hair, and he speaks in a gymnastic patter, leaping rapidly across fields of knowledge. Collison had also invited Tyler Cowen, a George Mason University economist who wrote the book *The Great Stagnation*. He and Cowen share an incrementalist way of looking at the world, often trading reading recommendations. (Since 2011, Collison has been posting lists of the books he is reading on his personal website.) Cowen had come with a stack of books. Collison went through the volumes, lingering over one about the British East India Company.

"I would love to read this. I find it super interesting, the East India Company," Collison said, "because they're an organization that really had to operate through values."

"And they were doing everything for the first time," Cowen said.

"And though none of them acquitted themselves well," Collison said, "the East India Company was not primarily predicated on slavery, unlike the others."

Many of the titles on Collison's reading list focus on the mystery of progress. He and Cowen would soon cowrite an essay for *The Atlantic*, calling for the creation of an academic discipline called Progress Studies to search fields like business, art, and medicine, with the aim of improving the productivity of society as a whole. Collison's obsession with the idea even shapes his recreational time. He has helped to organize an invitation-only conference for scientists and technologists called Borlaug Camp, named for the agronomist responsible for the Green Revolution. Over the Thanksgiving holiday last year, he jetted across four countries in Africa so he could "see

places where the Western notion that progress is inevitable is up for grabs," said Cowen, who drew up the itinerary for the trip.

Stripe Press (motto: "Ideas for Progress") emerged two years ago. It publishes books that appeal to Collison's imagination, like *The Dream Machine*, a formerly out-of-print biography of internet pioneer J. C. R. Licklider. In his immodest moments, Collison suggests that Stripe aims to complete the work begun by such early visionaries, by allowing people to transmit money as easily as ideas. Stripe's edition of *The Dream Machine* is a beautiful, hardbound artifact, and there is something nostalgic, too, in his veneration of an old view of progress, in which globalization and technology will inevitably result in betterment for the world. *—Andrew Rice*

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CULTURE

Helping the Creative Class Survive—and Thrive—on the Internet

Jack Conte

COFOUNDER & CEO / Patreon

For artists, singers, writers, and other creative types who are nice to have around if you enjoy a flourishing civilization, the internet has been a mixed bag. Yes, it provides a bottomless well of collaborators and ideas, along with the power to reach a nearly unlimited audience. But pesky thing, the internet also keeps finding new ways to destroy the economic basis for these folks to make a living, replacing it with flimsy ad-revenue-sharing deals. "A creative person can be reaching millions of people through this free distribution architecture and getting paid a few hundred bucks," says Jack Conte, a YouTube musician turned tech

CEO. "It sucks." (See "[The Alchemist](#)," issue 27.10.)

Conte's company, Patreon, aims to rescue the creative class from economic oblivion. "What we want to do is rebuild the infrastructure of the web so there's a better financial mechanism to—I guess to be crass about it—convert art into dollars." His proposition: Turn your most passionate fans into subscribers, or members of a club, and let Patreon facilitate that relationship. Since its founding in 2013, the company has sent nearly $1 billion from fans to creators, which suggests, if not a wholesale new model for supporting all artists, at least a very substantial lifeboat. —*John Gravois*

BLOCKCHAIN

Breaking Big Tech's Monopoly on Cloud Computing

Dominic Williams

PRESIDENT & CHIEF SCIENTIST / Dfinity

In the mid-1990s, when the internet was in its infancy, some companies thought they could build a better version of it. One of them was Microsoft, which envisioned a network that would be faster and more capacious, able to handle a new thing called multimedia. This was the infamous Information Superhighway. There was just one hitch: It likely would have been a proprietary network—a toll road. "Can you imagine how horrible that would have been?" says Dominic Williams.

We escaped that nightmare, but Williams says we've stumbled straight into another: [cloud computing](#). The cloud is now nearly as crucial as the internet itself, key infrastructure for data storage and high-powered processing. And it's dominated by tech giants like [Amazon](#), [Google](#), and [Microsoft](#).

Williams believes there should be a public option. He calls his plan the

Internet Computer. Think of it as an extension of the internet, with the tools of cloud computing baked into the protocol. And, like the web, it won't be controlled by a single company. Instead, it will be open, maintained by a Switzerland-based foundation (of which Williams' startup, Dfinity, will be a member) and powered by independent data centers worldwide. To preserve order (and security) in this decentralized system, Williams is using elements of blockchain technology.

> *The cloud is now nearly as crucial as the internet itself, key infrastructure for data storage and high-powered processing. And it's dominated by tech giants like Amazon, Google, and Microsoft.*

The idea is that little guys should be less dependent on Big Tech for computing infrastructure. But Williams goes further. He thinks the Internet Computer could spawn consumer tech companies that will build open services to mirror (and rival) tech giants. It's a fix, he says, for "platform risk": when a big company lures in startups to build products that rely on the giant's troves of user data, only to cut off access to that data later.

Taking on Amazon Web Services and Google Cloud? Overhauling the web's infrastructure? A skeptic could point out that it has already taken years, lavish funding, and top cryptography talent to design a system that's secure and usable enough to have a prayer at taking on Big Tech. But Williams is undeterred: "It's what we feel the world needs." He'll soon get a sense of what the world wants: A test version of the Internet Computer goes live this fall. —*Gregory Barber*

ROBOTICS

Preparing Humans for Life With Robots

Kate Darling

RESEARCH SPECIALIST / MIT Media Lab

A decade ago, Kate Darling asked a friend to hold a Pleo toy dino-bot upside down until it squirmed and whined. Because Darling isn't a sociopath, it upset her—and spurred her to begin exploring the strange new frontier of human-robot interaction. Now an outspoken researcher at MIT, she is writing a book, *The New Breed*, about our budding relationships with [robots](#) in the context of how we've treated animals throughout history.

Consider that in the Middle Ages, Europeans put cows and other animals on trial for killing people. They believed animals had moral agency. The temptation, as robots become more sophisticated and social, is to assume they're working with similar agency when really they're just a collection of 1s and 0s. "I don't think anybody wants to put robots on trial for crimes they've committed," Darling says, "but it shows we've had different solutions to this throughout history."

Darling wants us all to start grappling with the novel and powerful bonds that are sure to develop between humans and robots. "Do we need things like laws around assigning responsibility for harm because people have biases when interacting with robots that they don't have with other devices?" she asks. Best to find common ground now, because it's not so hard to imagine a future in which the bots are holding us upside down. —*Matt Simon*

CONNECTIVITY

Bringing Broadband Internet to Underserved Parts of the Globe

Unicef Ventures

It is a truth universally acknowledged—by the Allbirds-wearing set, at least —that a technological problem must be in want of a technological fix. So when a tech CEO hears that nearly 3.7 billion people around the world lack access to the internet, he gets to solutioneering. If the problem is that some regions are just too remote or too impoverished for telecom operators to cover profitably, he asks, then why not launch satellites to beam broadband to the masses from on high? All it'll take to close the digital divide is billions of dollars in R&D.

That's the tack [SpaceX](#), Amazon, OneWeb, and other companies are taking. But Christopher Fabian and his colleagues at Unicef Ventures, a kind of tech incubator within the United Nations, have a more earthbound approach. Their solution to universal connectivity is a program called GIGA, whose initials currently don't stand for anything. ("Isn't that nice?" Fabian says.) This being Unicef, the mission starts with kids: bring internet access first to schools and then, if all goes well, to the surrounding communities.

GIGA grew out of Project Connect, a machine-learning tool that combs through satellite imagery, identifies schools, and displays them on a map. (Schools everywhere have certain tells—soccer fields, early-morning lines of students.) The schools with consistent internet access get a green dot, while those without it show up as red.

That's where the tech fixes end and the diplomatic ones begin. First, Unicef Ventures will approach a head of state, or perhaps several from the same region, and offer to map all of their schools for free. This is a more tempting proposition than you might think: In Colombia, the tool spotted some 6,700 schools that weren't on official maps. The team's goal is to reach 130 countries by the end of 2021, at a cost of about $30 million. They've mapped 15 so far.

Next comes the financing. Before a telco can be talked into turning the red

dots green, it needs a guarantee. " 'Do good' doesn't usually fly," says Sunita Grote, the manager of Unicef's Innovation Fund. A group of countries in, say, Central Asia will put together a joint bid, bankrolled with some combination of public funds, low-interest loans, debt and equity financing, and a sliver of cryptocurrency. Fabian acknowledges that crypto talk invariably "makes you sound really nutty," but the advantage is that blockchain transactions are trackable and auditable. If a service provider fails to hold up its end of the bargain, everyone knows it.

Once the school is connected, the rest of the community can piggyback off of it, buying a share of the available bandwidth. (In especially far-flung areas, Fabian says, the bandwidth may come from those tech companies in orbit, whose signals can go where utility trucks can't.)

The next phase of the project really excites Fabian. With funding from the government of Norway, his team is building a kind of nonprofit App Store stocked with free pedagogical software and "nerdy little open source projects." As connectivity expands, the customer base for these "digital public goods" will swell. An education minister in the Caribbean, for instance, might go to the GIGA store for a VR training tool, because it's too expensive to fly students to a neighboring island for engineering classes.

GIGA's goal of universal connectivity is years away, but Fabian and his colleagues remain energized. Some of the staff in New York—26 people holding 20 different passports, he boasts—joined the team from Facebook, Google, and other corporate juggernauts. "We have a purpose for being here, and that's really nice," he says. A project like GIGA is a bottom-up antidote to Silicon Valley's business model. "This," he adds, "is rewriting the internet." —*Anthony Lydgate*

TRAFFIC CONTROL

Tracking All the Debris Threatening Earth's

Orbital Highways

Moriba Jah

DIRECTOR / Astria

Outer space may be infinite, but these days it's starting to feel a little crowded. An estimated 500,000 human-made objects are hurtling around our planet right now. Some of them beam GPS signals to our phones or premium programming to our TVs; others fill scientists' hard drives with up-to-the-minute climate readings and glamour shots of the cosmos. More than 99 percent of what's up there, however, is just [plain junk](—)—spent rocket boosters, exploded satellites, runaway flecks of paint. NASA and the Department of Defense don't know what, or where, much of it is. That makes getting to space a bit like merging onto the highway without using your mirrors. Also, all the other cars are going more than 6,700 mph.

> *An estimated 500,000 human-made objects are hurtling around our planet right now. More than 99 percent of them are junk.*

"I predict really bad things happening if that does not change," says Moriba Jah, the 48-year-old director of Astria, the Advanced Sciences and Technology Research in Astronautics program at the University of Texas at Austin. Even those flecks of paint, moving at orbital speeds, are enough to seriously damage a spacecraft. Jah, a beachcomber for the space age, uses big-data analysis to locate and identify larger debris. Last year, he and his colleagues launched a demo version of AstriaGraph, a kind of open source traffic monitor for the heavens that takes the often conflicting data from satellites and ground-based sensors and combines them into a 3D display.

Born in San Francisco to immigrant parents, raised in Venezuela, and trained

at NASA's Jet Propulsion Laboratory, Jah didn't expect to spend his career tracking space trash. It seemed like "the most unsexy, unappealing thing you could do in life," he says. But 20 years later, Jah sees it as the key to ensuring the sustainability of space exploration. After all, it's not just national space agencies contributing to the congestion anymore. Private companies plan to deploy thousands of small satellites in the coming years, at least tripling the total number in orbit and greatly increasing the risk of a collision. Jah can't enforce the rules of the road for these new operators, but he can, at least, give them a map of where they're going. —*Daniel Oberhaus*

DEEPFAKE DETECTING

Creating Tools to Suss Out Manipulated Digital Images

Hany Farid

RESEARCHER / UC Berkeley

In 2001, Hany Farid was frustrated. He just couldn't beat his long-standing tennis buddy. To make light of his hopelessness, Farid, then a computer science professor at Dartmouth, made a fake. He used Photoshop to paste his friend's head onto the shoulders of a professional tennis player. (He thinks it was Andre Agassi.) As he stretched the face to make it fit its new physique, he realized that the algorithm Photoshop used to perform the operation would leave a characteristic signature on that part of the image. Farid had previously specialized in computer vision, getting computers to understand pictures more as humans do. But now he set about establishing a new field of image science, developing methods to detect when digital photos had been manipulated. Today, he's one of the leading authorities on detecting fake photos.

Farid sensed all those years ago that as digital cameras became more

common, photos would become less trustworthy. Computer files, so easily modified, were more corruptible than film negatives. A succession of techniques he invented to spot fakery were quickly pressed into use. Farid worked with prosecutors to convict child abusers and helped fishing contests spot when anglers had faked the true size of their catch.

In 2017, Farid's satisfying but niche specialty took on new significance. A Reddit account called deepfakes posted pornographic clips with the faces of actresses like Gal Gadot pasted on other bodies. The videos were made using a tool—which the account soon released online—based on machine learning.

The latest on artificial intelligence, from machine learning to computer vision and more

Deepfakes quickly became a catchall term for any image, video, or audio fabricated or altered by machine learning. In the past two years, hobbyists, academics, and entrepreneurs have made AI fakery much more convincing, and deepfakes have become a tool of online harassment. With the 2020 presidential election approaching, Farid and others are concerned that these manipulations, spread on social media, could enable mass deception—potentially skewing elections by showing a candidate saying or doing something they did not. "This used to be a boutique little field, but now we're defending democracy," Farid says. "What happens when more than half the content you see and hear online is fake?"

One of Farid's favorite clips in his personal library of deepfakes underlines that troubling question. It shows Hillary Clinton standing at a podium and making campaign pledges she never made. As she utters lines like "Vote for me and I promise I will be a stone-cold B," winking archly, not-Clinton's face appears indistinguishable from the real thing.

That clip was made by computer graphics researchers at the University of Southern California. They added a photo-real re-creation of Clinton's visage over the face of actress Kate McKinnon in a *Saturday Night Live* skit. The

USC group is trying to make better digital manipulations for the entertainment industry, but they also send their best work to Farid, who is now at UC Berkeley, so he can test the power of his detection tools.

> *"This used to be a boutique little field, but now we're defending democracy. What happens when more than half the content you see and hear online is fake?"*

Farid's latest detection method can easily see through the fake Clinton. It works by analyzing verified videos to build up a signature of a particular person's habitual, characteristic facial movements. New clips can then be compared with that signature to see if they contain the same pattern. McKinnon is a good mimic, but she doesn't move her face exactly as Clinton does.

Technical tools alone can't stop deepfakes, though, and the false images will only grow more sophisticated. Farid is talking with policymakers in the US and Europe about how new laws could criminalize malicious deepfakes or force internet companies to work harder at detecting them. Despite the gloomy portents, though, Farid still finds fun in fakes. He recommends a YouTube clip in which [Nicolas Cage's face](#) replaces that of Julie Andrews in the opening scene of *The Sound of Music*. (WIRED does too.) "They're hysterical—we should welcome and encourage it," Farid says. "But let's put safeguards in place." —*Tom Simonite*

NATIONAL SECURITY

Collecting Signals to Defend the 'Nation's Most Sensitive Networks'

Anne Neuberger

DIRECTOR / NSA Cybersecurity Directorate

In August 2016, a group called the [Shadow Brokers](#) popped up on Twitter touting a brazen cybertheft: It linked to a trove of hacking tools stolen from the National Security Agency. The know-how of one of the top intelligence agencies in the US had been released into the wild. Criminals and foreign government hackers seized on the tools, and within months [North Korea](#) was weaponizing them to inject ransomware onto 300,000 computers in hospitals, telecoms, and energy firms around the world.

Now, three years after that disastrous data dump, the NSA has established a Cybersecurity Directorate. Its leader, Anne Neuberger, is tasked with creating a conduit between siloed parts of the agency. By sharing information about threats and new hacking techniques used by adversaries, the agency hopes, among other things, to protect itself against new types of attacks.

Neuberger came to the NSA in 2009, having worked in the private sector and the Department of Defense and Navy. The daughter of a Hungarian Jewish refugee, she grew up in an Orthodox community in Brooklyn. There, she once said, she saw "women who raised large families, ran community organizations," and they inspired her to "just not talk, get it done."

Neuberger helped establish [US Cyber Command](#), which conducts digital combat operations. And she was working at the NSA when Edward Snowden leaked information about the agency's mass surveillance initiatives. That event led Neuberger to be named the NSA's first chief risk officer.

The Cybersecurity Directorate is part of a larger shift in the intelligence world. Once a sideshow, cyberspace operations have moved to center stage. The safety of everything from electric grids to voting records is at

stake, and digital defense needs to keep pace. As Neuberger told WIRED, "We're focused on security of the nation's most sensitive networks." —*Lily Hay Newman*

Three questions for …

Astro Teller

CAPTAIN OF MOONSHOTS / X

1. X is all about far-out ideas that solve massive problems. How might tech help us fix the climate crisis?

Radical improvements to, or radical creative reuses of, technology are necessary but not sufficient to solve the climate crisis. If you were to try to solve the problem purely through public policy and social solutions without any real changes in technology, you would be asking people to give up a lot of their quality of life. That's not realistic, which is why technology has to be an important part of the solution.

2. What about geoengineering schemes, like spraying aerosols in the atmosphere to reflect the sun's energy?

We learn by sandboxing so we can try things safely. A lot of geoengineering tends to get ruled out. Anything that has to be done at a planetary scale and can't be rolled back is not amenable to "Well, let's try it and see."

3. How can X projects like molten-salt energy storage and a wind-- harvesting kite make a big impact?

Microgrids would open up a lot of opportunities for things like energy kites in remote areas. Rather than spending lots of money to do things in the traditional way, especially on infrastructure, bet on new technologies and you'll end up getting a better outcome at a tiny fraction of the cost and

carbon footprint. —*Matt Simon*

FLESHED OUT

The modern livestock industry is one of the most resource-intensive and ethically fraught sectors of the global economy. The extraordinary land use and methane gases produced by the beef industry in particular will rise to unsustainable levels, as more people in the developing world add meat to their diets. That's why Pat Brown and Uma Valeti are each blazing their own path to eliminating the livestock business as we know it. Whether it's Brown's plant-based meat alternatives or Valeti growing meat in tanks, we're rooting for both of them.

FOOD SCIENCE

Replacing All Animal-Based Meat With Plant-Based 'Meat'

Pat Brown

FOUNDER & CEO / Impossible Foods

Back in 2009, Pat Brown set off on a sabbatical from the department of biochemistry at Stanford, intent on identifying the most important problem in the world that he could help solve. That, he eventually decided, was the impact of animal agriculture on the environment. By July 2011, Brown had founded [Impossible Foods](#), hired a team, and set off on a five-year journey to develop a plant-based replacement for meat.

The big hurdle, of course, was making something that tastes so good people would give up the real thing: "The most urgent, important scientific question in the world is what makes meat delicious," Brown says. Off the bat, the team at Impossible dove into the science behind meat's flavor, texture, and juiciness, and how those properties change as it's cooked.

To nail the flavor factor for a plant-based meat substitute, the team came up with one key ingredient: heme, a molecule containing iron that's found in animal blood but also exists in plants. Impossible's version is produced by genetically modified yeast.

Quantis International, a sustainability consulting firm, analyzed the Impossible Burger production process and found that it uses 87 percent less water, creates 92 percent less water pollution, emits 89 percent fewer greenhouse gases, and requires 96 percent less land than the traditional production of beef. That bit is crucial; clearing land for livestock is the leading driver of habitat loss around the world and has been connected to the devastating fires in Brazil's Amazon rain forest—more than 90,000 blazes so far this year.

Since 2016, the Impossible Burger has appeared on the menus of select restaurants, like David Chang's Momofuku Nishi, but it hit the mainstream when White Castle put it on the menu in April 2018. Then, Burger King introduced the Impossible Whopper earlier this year, driving up the franchise's foot traffic by 18 percent, according to consumer data firm inMarket inSights. Grocery stores in Southern California started selling the product this fall. Brown says he hopes his alt-meat will one day totally replace animals as food. He wants his company's burger to be better than the real thing. "We can continue to innovate forever," he says. "The cow stopped innovating years ago." —*Meredith Fore*

BIOENGINEERING

Replacing Slaughtered-Animal Meat With Cell-Based Meat

Uma Valeti

COFOUNDER & CEO / Memphis Meats

Uma Valeti loved meat. But he didn't eat it. Cruelty to animals was something he just couldn't stomach. Fortunately, Valeti was also a cardiologist who worked on regenerating human heart muscle with stem cells. So he cinched up these two parts of his life and became cofounder of the first cell-based meat company, Memphis Meats.

With cell-based meat, conscientious carnivores can have their steak and eat it too: real animal flesh, no slaughter necessary. Muscle cells from animals are placed in a bioreactor—similar to the tanks used to brew beer—and supplied with a combination of nutrients, vitamins, and minerals to help them grow and multiply. Three to six weeks later, the raw meat is pulled from the tank, ready to be seasoned and cooked.

The challenge, though, is scale. Memphis Meats' first meatball cost about $1,200 to make. Valeti says that improvements in the production process have lowered that figure by "multiple orders of magnitude." (The company also has a proprietary soup of nutrients.) Valeti won't yet share the current cost, but he says his product would not be the most expensive meat on the menu if it went to market today. Memphis expects to start shipping its meat to stores in the next few years.

Global meat production is expected to almost double by 2050, and the resulting toll in land, water, and fossil fuel use under traditional methods of production would destroy ecosystems and hasten climate change. That's one reason agribusiness giants Tyson and Cargill have invested in Memphis Meats. The long-term potential for actual cost savings is, of course, another. (It's hard to pin down the environmental footprint of cell-based meat—none of the companies are producing at scale—but it's expected to be a lot smaller than that of Big Ag, and a lab uses a lot less land than a pasture.)

"We're not asking people to switch their behavior," Valeti says. "We're all in this to feed the world." A worthy goal, as long as the world can get used to the idea of eating meat from a tank. —*M.F.*

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