NAUTILUS

Technology's New Face

WHAT IF AI TOOK OVER? p.20

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A Cautionary Tale

ONE OF THE BRIGHTEST KIDS in my college class had a sticker on his laptop that read "nothing else matters." When I asked him what that meant, he told me it depends. At the time it meant building new devices—lasers, circuits, batteries. The kinds of new technologies that we all knew were changing the world fastest, and the reason we'd chosen our program.

A year or two later, things had changed. "Why try to solve these really difficult problems one at a time?" he asked me in class one day. "We should just solve one problem, once, and be done with everything." He was referring to artificial intelligence.

Precocious, young, technically-minded kids tend to drift toward theories of everything. The most universal answer promises the deepest insight, the greatest explanatory power, the best surprises. Every field has its program of foundational questions. But underneath all of them is the same engine of progress: intelligence.

In this issue's cover story, Max Tegmark, a professor of physics at MIT and the president of the Future of Life Institute, imagines what might happen if a group of researchers succeed in developing a super-human artificial general intelligence. In the story, the technology produces rewards of the first order: scientific breakthroughs in every field, equality, peace, and prosperity. But they come at a cost.

Human society becomes the child of an invisible parent. Every gain comes at the expense of an immense transfer of power. The present is greatly improved, but the future becomes obscure. Having gained control, what will the people who run the AI do next? And what if the AI begins to form its own opinions?

The story reminds us of why Elon Musk, Stephen Hawking, and other members of the Future of Life Institute challenge us to think cautiously about AI. It's not because robots will come to kill us, and not (or not just) because we might lose jobs.

It's a more universal question, and one that spills past the boundaries of science and technology altogether: How will humans stay relevant?

Welcome to the September/October 2017 *Nautilus* print edition.

—Michael Segal
Editor in Chief

Contents

Preludes

Cover Story

Themes

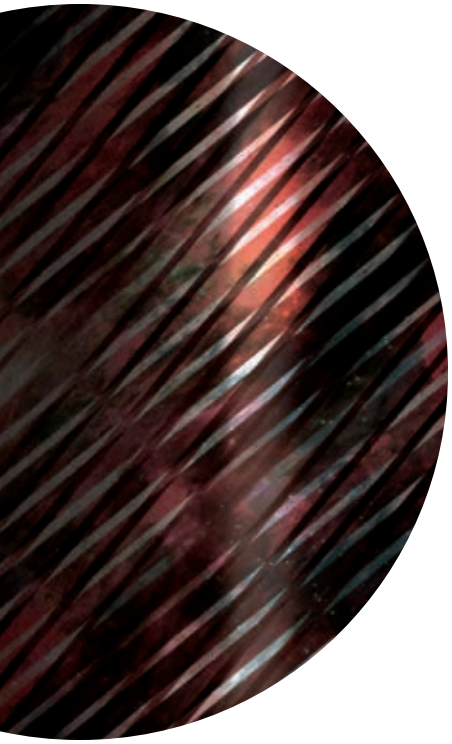
Each print edition identifies different themes in science and explores them from multiple perspectives.

COVER Sophy Hollington
BACK COVER Vedanti Sikka

VEDANTI SIKKA

52

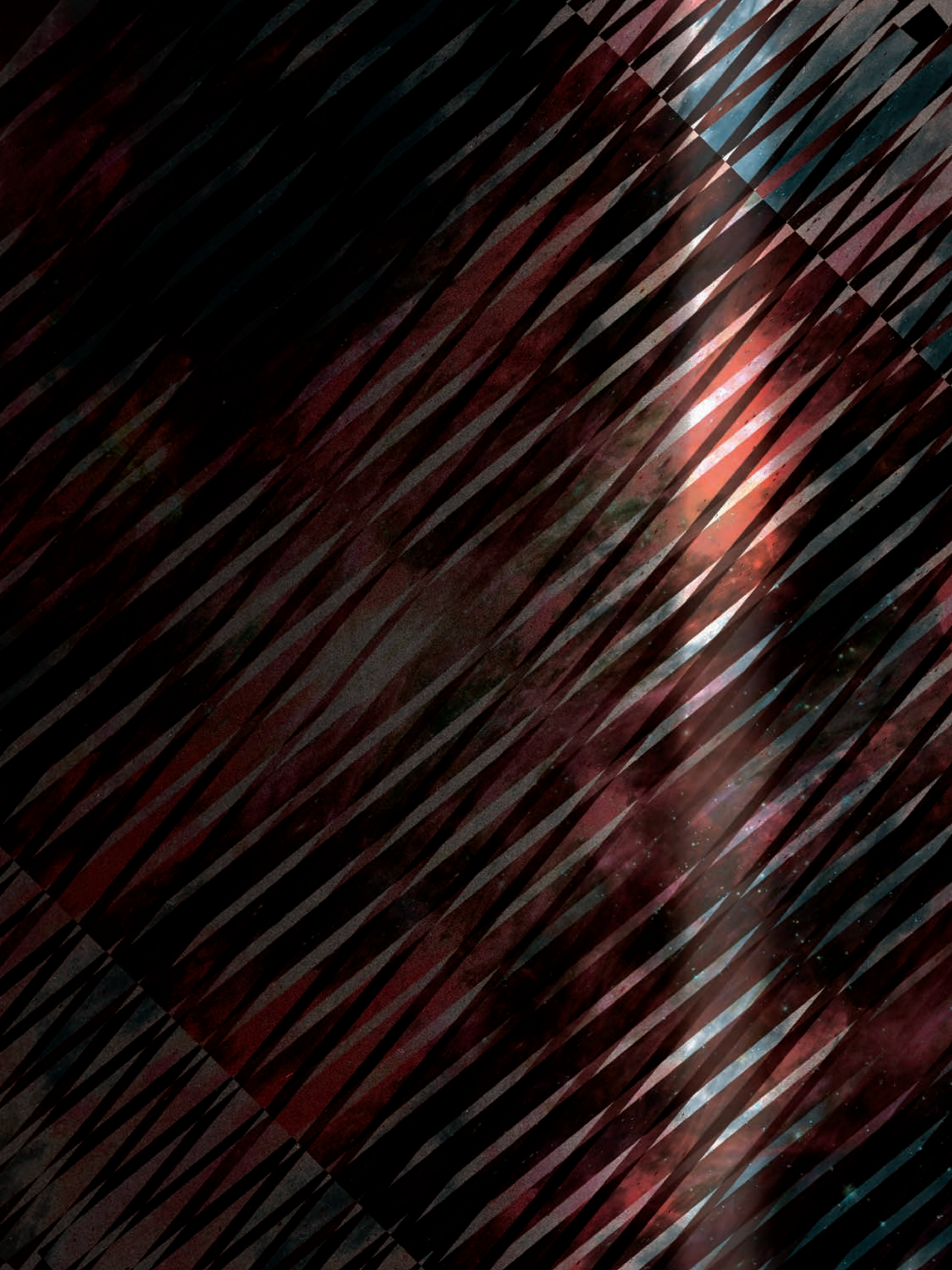
The Hive



"It is at heart a story about two individuals that can choose to cooperate or cheat."

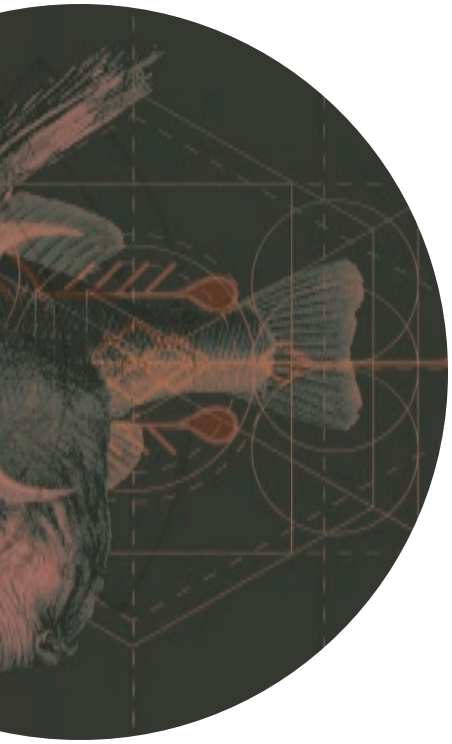
—Simon DeDeo, p.58

TITLE ART Vedanti Sikka



53

Monsters



"Some species of octopuses temporarily recode their genes."

—Regan Penaluna, p.76

TITLE ART Jessica Lin

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Letters

Reader responses to the July/August 2017 print edition.

"WHY YOU NEED EMOJI"

Language, whether written, spoken, in body or emotive forms, is always in flux. Malleable, it is something that is always progressing. This is the reason why even the meanings of words change in time, as do their spellings and pronunciations. The use of emojis today is a natural progression and we should embrace this.

—*Sean*

The thing most commentators (and the article) seem to forget is that these emojis grew out of the tech community—the early adopters of Internet chat, who tended to be educated, technical, creative, curious people. They naturally identified the need for things like smileys—the old colon-bracket :) and the semi-colon-bracket ;) wink to replace the tone of voice. It was a way of reducing conflicts in text chat and bulletin boards, which could otherwise get heated—exactly the way such real-life body languages evolved in the real world. It wasn't invented by or for kids originally—it displayed an emotional intelligence of some note—and only attracted the snobbish dismissiveness in the majority of comments as it became more mainstream.

—*Leia Fee*

"THE STRANGE SIMILARITY OF NEURON AND GALAXY NETWORKS"

A fascinating peek into the remarkable fractal properties of the universe across different levels. As each system is drawn toward higher entropy states, it seeks configurations of stable structures that dissipate energy, maximizing efficiency and exporting entropy to the larger environment. The visible results are often in the shape of spirals—spiral galaxies, whirlpools in flowing water, the interlocking spirals in the head of a sunflower, murmurations of flocking birds. What drives the emergent cascade across time and across levels, from the smallest to the largest of scales?

—*George Gantz*

"EMOTIONAL INTELLIGENCE NEEDS A REWRITE"

Very interesting and useful reframing of the concept of EI. I wonder what Professor Feldman thinks about cognitive biases and innate emotional responses, though. She says the brain "receives only the sensory effects of what is going on in the world—the sights, sounds, smells, touches, and tastes that come through the body's sensors." The black-box, data-processing model of the brain. But emotion and cognition both come from more

than conditioning. The brain is full of biases at every level. Cognitive biases, at the level of concept; linguistic biases from words (or absence thereof) in our working vocabularies (as the article wisely points out). Emotional bias, too, from the exigencies of our evolved hormonal and neural architecture.

—*Jesse Jones*

Nautilus *welcomes reader responses. Please email* letters@nautil.us. *All letters are subject to editing.*

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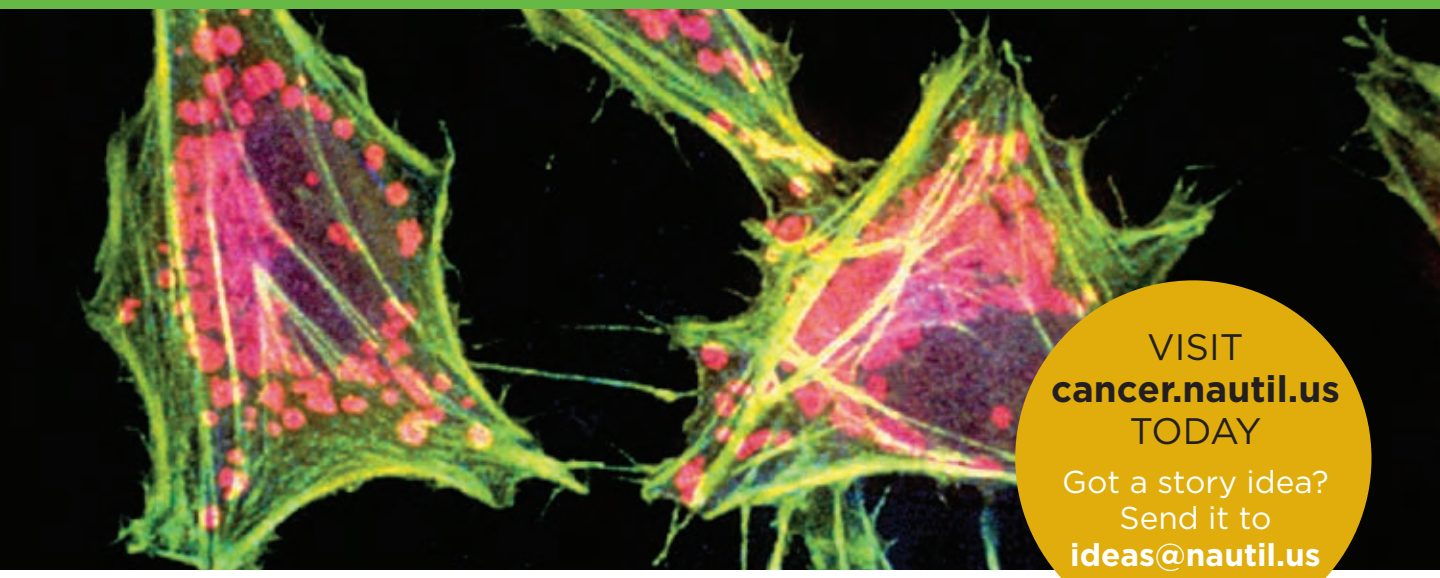

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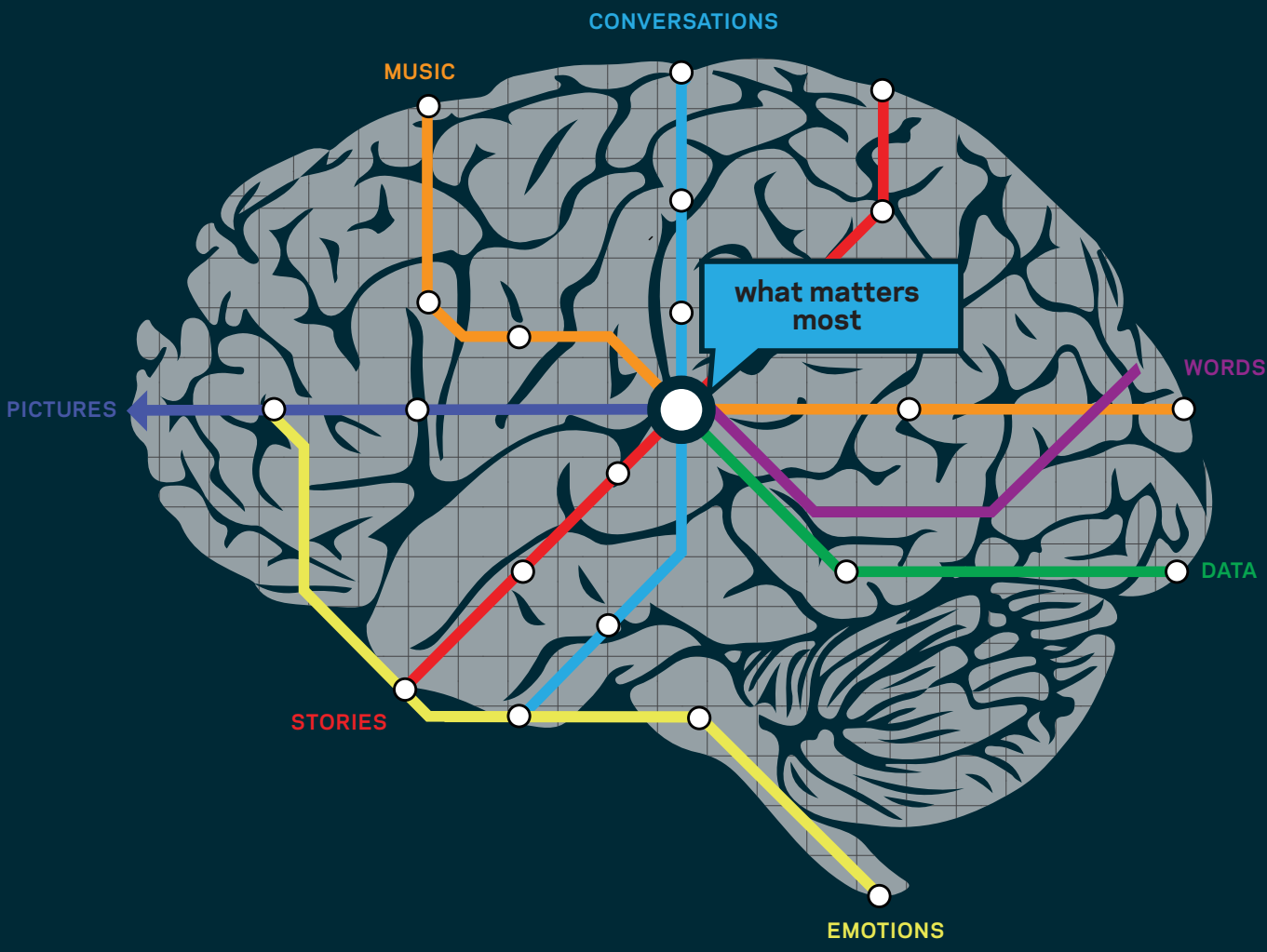

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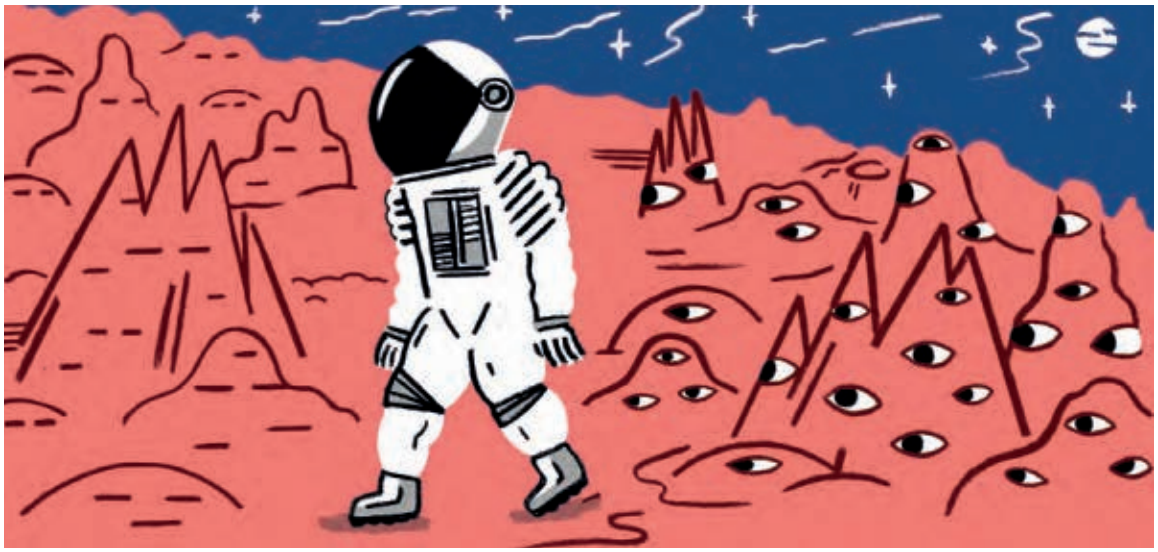
Preludes



ALIENS

How to Depict a Plausible Alien Ecosystem

YOU MIGHT EXPECT SCIENTISTS to heap scorn on Hollywood's depiction of aliens, but they're generally forgiving. Dirk Schulze-Makuch, an astrobiologist at the Technical University of Berlin, remarks that most science-fiction aliens are either riffs off the weird life we see in Earth's deep ocean, such as the squid-like creatures of *Arrival*, or versions of now-extinct animals from earlier in our planet's history, like the adult trilobite in *Prometheus*. And that's not a bad strategy.

"If you want to study a lot of different body shapes or forms, look at the Cambrian Explosion," he says. "If you look at a museum exhibit of life from 500 million years ago, you see a lot of variety."

What irritates him and others isn't what movie aliens look like, but the magical things they do. Leave aside their physics-defying technology and consider just their most basic attributes, such as metabolism. "*Prometheus* was especially terrible this way," says Caleb Scharf, the director of astrobiology at Columbia University. "[It had] the idea that a little thing can grow into an enormous thing when you're not looking, even though there's nothing to eat."

The magical things aliens do is what irritates scientists.

Jim Cleaves, a biochemist at the Institute for Advanced Study in Princeton, New Jersey, has the same complaint about the movie *Alien*. "The alien always bothered me," he says. "Somehow it manages to turn a few pounds of biomass into several hundred pounds of really hyperactive alien really quickly, without eating anything."

It's precisely the mundane concerns that will help scientists identify life. No matter what form it

ILLUSTRATIONS BY KATI SZILAGYI

takes, life in the universe needs a metabolism. It has to take in energy in order to grow and maintain its daily needs. Another essential quality is that living things do not exist in isolation; they evolve in response to their environment.

"The one that always bugged me was *Starship Troopers*," Cleaves says. "The giant colonies of 'bugs' on their planet seems the equivalent of having herds of buffalo, and nothing else, running across the Sahara Desert. What do they eat? Where is the water?"

"Evolution does what it has to, and no more," Scharf says. "The biggest criticism in those alien depictions is they're not thinking through how a real ecosystem works. Evolution doesn't say, 'We need a monster here.' "

In both science and art, the central challenge of thinking what an alien could be is that if something is too alien from us, we probably wouldn't recognize it. It has to be different enough from us to be truly alien, but not so beyond our experience that we wouldn't be able to identify it as a living entity.

Scharf says the silicon-based Horta from the *Star Trek* original TV series episode "The Devil in the Dark" is one of the best examples of an alien that strikes this balance. The Horta are at first not even recognized as living creatures because they look like rocks.

"It was clever, because it raised the idea of something so different, and yet there is life there, an alien presence where you can almost understand what it's up to," Scharf says. "That was one of the most sensitive depictions of something being really alien, but not so alien that you couldn't recognize it."

Our fictional imaginings of aliens almost always presume they are intelligent. That's a necessity for such tales, because without intelligence, it's hard to come up with a good story; even a simple predator/prey situation requires some intelligence. But many scientists think the odds of alien life being intelligent are not that great.

"We may live in an empty universe, where the origin of life is difficult," Schulze-Makuch says. "But if that is not the case, there will be a lot of life, and complex life, too. We don't know about technologically advanced life—that may be very rare. As far as we know, it only happened once on Earth. We don't have technologically advanced kangaroos or dinosaurs, for instance."

The rarity of intelligence in the universe would be a depressing answer to why we haven't seen aliens yet: Most aliens haven't evolved much beyond eking out existence on their own planets. We may not be the first species in the cosmos, but we might be the first to look up at the stars and imagine who else might be out there.

—Leslie Mullen

HEALTH

This Man's Immune System Got a Cancer-Killing Update

"This type of thing doesn't happen in medicine."

WILLIAM LUDWIG WAS 64 when he received a near-hopeless cancer prognosis in 2010. The Abramson Cancer Center at the University of Pennsylvania had run out of chemotherapeutic options. In a later interview, scientist Carl June described Ludwig's condition as "almost dead."

Alison Loren, an oncologist at Penn, had been taking care of Ludwig for five years. If chemotherapy is not effective early on, each new round brings diminishing returns, and it becomes more and more toxic, she told me. In Ludwig's case, its toxic side-effects were outdoing any progress.

It was about that time when Loren approached Ludwig about a new, untested treatment.

Antibodies normally bind to molecular markers called antigens, tagging them to be disposed of by scavenger cells. Then other immune system cells, like helper T-cells, notice the resulting structure, lock onto it, and unleash signaling molecules called cytokines to stir up the immune response. Killer

T-cells also carry out lethal attacks on microbes carrying unauthorized antigen badges. T-cells carry a powerful thwack on their own, but are less effective without the precision targeting of the antibodies.

Zelig Eshhar, an immunologist at the Weizmann Institute in Israel, came up with a plan to combine them. He invented "chimeric antigen receptor T-cells," or CAR-Ts, first describing them as "T-bodies." They were made up of scrambled viruses carrying a new human gene. Once in human cells, the gene would build a new receptor on T-cells that would mimic the targeting function of antibodies, helping them lock on to cancerous cells.

Some of Ludwig's T-cells would be edited by a virus to install a synthetic gene in his genome, which would in turn code a protein to build a receptor enabling the T-cells to recognize a certain cell surface marker on Ludwig's cancerous cells. Hopefully, after the doctored cells returned to his blood system, they would go on the attack.

He was checked into the hospital on July 31, 2010. For a few days after the doctored cells returned to his blood system, nothing happened. But then, 10 days later, chaos broke out. Ludwig's whole body began to shake. His heart rate shot up, his blood pressure collapsed. He got a fever.

"A cytokine storm," Loren told me. "The engineered T-cells were 'engrafting' in the body, meeting up with target antigens, and unleashing a whirlwind of cytokines." Those signaling molecules were firing up the immune system, stirring fevers and opening capillaries so immune cells could rush through the blood stream. The storm lasted only hours, but was incredibly intense. And just as quickly as it began, the storm was over.

Almost a month later, Ludwig's bone marrow was tested for cancer. And there were no sheets of cancer cells in the bone marrow. "I couldn't believe it. This type of thing doesn't happen in medicine," Loren told me.

June estimated Ludwig's genetically engineered T-cells had wiped out two pounds of cancer in less than a month. Soon there was a Patient Number Two, and then, a third. Doctors saw it wipe out a range of 3.5 to 7.7 pounds of cancer in a matter of days among three different patients. Within a few years, hundreds of patients saw their bodies cleared of cancers. But not all cancer patients responded positively. And no one knew why gene therapy threw some patients, like Ludwig, into violent convulsions and tremors, and others responded with only a slight fever.

—Jim Kozubek

Adapted from *Modern Prometheus.*

ECONOMICS

Your Life Is Worth $10,000

IF YOU HAD TO PUT A PRICE on your life, what cash amount do you think it would be? What about $100,000? That was the amount that a group of kidnappers in Atlanta demanded in exchange for a woman's life in June of 2016. Not high enough? Well, in a statistical sense, certain government agencies value a human life significantly more. In 2010, for example, both the Environmental Protection Agency and the Food and Drug Administration put a price on human life: $9.1 million (in proposing stricter air pollution regulations) and $7.9 million (in proposing new cigarette warning labels), respectively.

Most of the global tobacco epidemic is still in our future.

On its website, the EPA stresses that this figure isn't like the ransom. "This is not an estimate of how much money any single individual or group would be willing to pay to prevent the certain death of any particular person." The estimate is instead what it calls the "value of a statistical life." How do they calculate that? Imagine you and 99,999 people are asked how

much you'd be willing to pay to reduce your personal risk of dying in the next year from 1 in 100,000 to something lower. Suppose the average response was $100. That would mean the group would be willing to pay $10 million (100,000 people paying $100) to save "one statistical life."

But unlike government organizations, which use this number as a measurement for how much should be spent to prevent a death, the tobacco industry values people's lives mostly according to profit.

The tobacco industry spends billions on advertising, packaging, and manufacturing cigarettes. After subtracting all those costs, the profit margin per smoke is practically a penny. Last year, 258 billion cigarettes were sold in America alone.

People's lives end up being worth about $10,000 to tobacco companies. On average, one person will die for every 1 million cigarettes smoked. As Robert Proctor, a Stanford historian, said in a 2013 paper:

> Cigarette companies make about a penny in profit for every cigarette sold, or about $10,000 for every million cigarettes purchased. Since there is one death for every million cigarettes sold (or smoked), a tobacco manufacturer will make about $10,000 for every death caused by their products. Otherwise put: A cigarette manufacturer will not forgo $10,000 in profit, even if this means the death of one of their customers. The value of a human life to a cigarette manufacturer is therefore about $10,000.

The low price the tobacco industry puts on human life has helped lung cancer become "a major source" of disease, death, and health care costs worldwide, according to a 1998 article in the *Journal of Clinical Oncology*. The estimated costs to society from the effects of smoking are over $300 billion a year in the United States, vastly more than the revenue earned by taxing the tobacco industry, which amounted to nearly $14.3 billion for 2014.

Two decades ago, smoking was, even in strict economic terms, a net cost to society, but we seem to be diminishing its negative impact. Taxation on cigarettes has continued to increase, and, according to the U.S. Surgeon General's 2014 report, smoking decreases by 4 percent for every 10 percent hike in the price of cigarettes.

It may be a while until death rates from tobacco-caused lung cancer start to go down worldwide. Most of the global tobacco epidemic is still in our future. "Cigarettes cause about 1.5 million deaths from lung cancer per year, a number that will rise to nearly 2 million per year by the 2020s or 2030s," according to Proctor. "The fact is that cigarette use persists, and on a massive scale," he writes. "Global cigarette use seems to have peaked at about 6 trillion cigarettes sometime after the turn of the new millennium, but the deadly effects of this epidemic will still be felt for decades."

—Matthew Sedacca

ONE QUESTION

COURTESY OF AARHUS UNIVERSITY

Mathias Clason

How does evolution constrain the sorts of monsters humans can find scary?

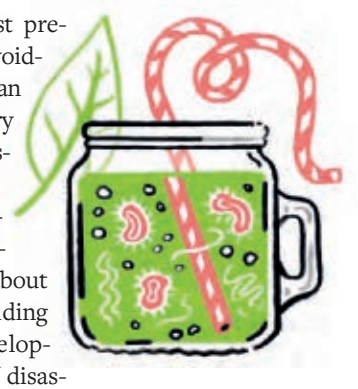
Associate Professor of Literature at Aarhus University

The scariest monsters are the ones that match or over-match the input specifications of the human fear system—an ancient, evolved defense mechanism. Our ancestors found themselves in environments that teemed with danger—from predators, creepy-crawlies, invisible pathogens, and hostile others—and that dangerous existence left deep traces in our constitution. Social exclusion could mean death, especially in the dark. Modernity has eradicated or counteracted most of those ancestral dangers, but they live on as ghosts in the human nervous system, reflected in scary folktales like *Jaws*, *Cloverfield*, and slashers. Conversely, it's hard to fear smoking tobacco, eating trans fats, and changing the climate. Natural selection did not prepare us for evolutionarily novel dangers. But research suggests that we can harness the power of fiction to make even abstract or distant threats salient. Showing what happens to believable, sympathetic characters engages us more powerfully than rational but abstract arguments.

FOOD

What to Eat After the Apocalypse

HOW CAN HUMANKIND best prepare for an apocalypse? Avoiding starvation will become an urgent question—and a very hard one, if some global disaster disrupts our food production.



It's not like you have to eat insects raw.

Joshua Pearce, an associate professor of engineering at Michigan Technological University, began to think about this question while working on providing low-cost drinking water to the developing world. He found the prospect of disaster terrifying. We'd be "no better off than the dinosaurs, despite all of our technical progress," he told me. "Humanity is too smart for that."

Pearce partnered with David Denkenberger, a research associate at the Global Catastrophic Risk Institute. The two engineers developed a set of solutions that they believe would provide five years of food for the Earth's population, and published them in their book, *Feeding Everyone No Matter What*. *Nautilus* spoke to Pearce to find out how to survive the apocalypse.

What kinds of disasters do you think about?

Let me take the most likely one: the nuclear winter case. Say two countries that both have access to nuclear weapons get very angry at each other, and then retaliate, destroying most of the major cities in the opposite country. The vast bulk of humanity would survive. Ninety-five percent of us would still be alive. But then as those cities burned, you'd end up getting soot in the upper atmosphere that stays there and darkens the entire planet. And all the crops fail.

A few of the more hearty crops, like trees, could survive a little while. But your wheat, your rice, your corn? That's all dead. You don't get that harvest, and that's what we feed the world with. As those crops fail, you'll start to get hungry; you'll start going into your stored food supplies. The historical assumption is that's when we all go completely crazy. It's bad.

What would we eat then?

There are many things that you can eat that we don't normally consider food, particularly in the West. Leaves are one of them. You can eat leaves. You just have to be careful about how you do it. Leaves are high in fiber and we can't digest any more than half of it, but if you chew the leaves and spit out the fiber you can draw out nutrients from it. Or you can make teas.

Tea in particular is a relatively easy one to do. Pine needle tea has more than 100 percent of the vitamin C of orange juice. You could actually make pine needle tea from the pine tree in your backyard and get your vitamin C for the day. It's actually a really good superfood.

The other obvious one is insects. The conversion ratios between biomass and food in insects is much better than say, in cows. There are actually quite a few people throughout the world that eat insects today and, for feeding everyone, it is a very obvious solution. It's not like you have to eat insects raw. You would never know the difference between say, a sausage patty, a veggie sausage patty, and an insect sausage patty. It's all the same! It's just the spices. Let the food scientists go crazy on it.

Have you tried some of these solutions yourself?

Absolutely. A lot of it was just to make sure the taste wasn't so bad that it would never happen. Stuff like pine needle tea is really not that bad. Many insects are, I would even go so far as to say, tasty? If you get by the initial sort of gag reflex.

—Yvonne Bang

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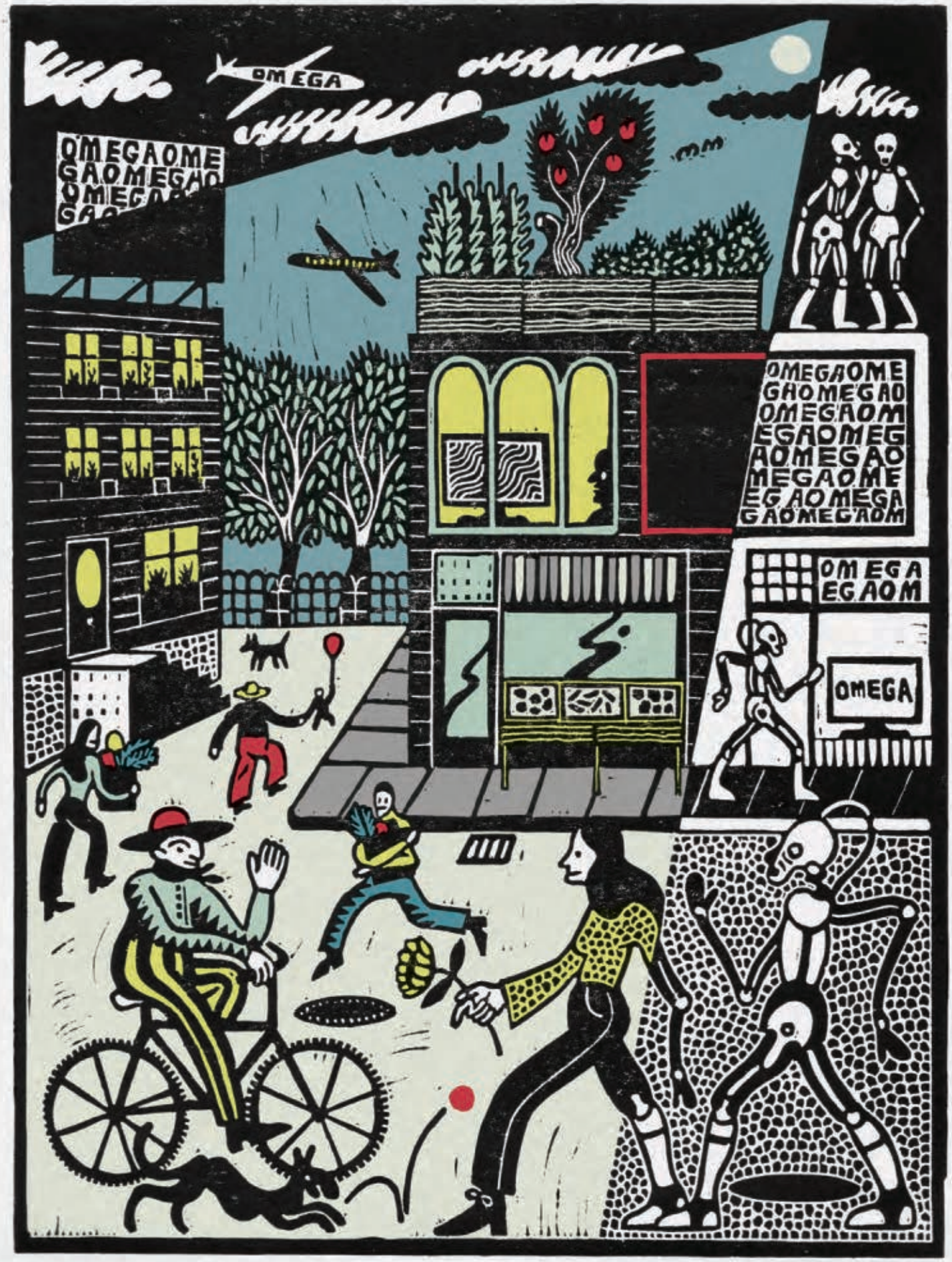
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The Last Invention of Man

How AI might take over the world

BY MAX TEGMARK

THE OMEGA TEAM was the soul of the company. Whereas the rest of the enterprise brought in the money to keep things going, by various commercial applications of narrow AI, the Omega Team pushed ahead in their quest for what had always been the CEO's dream: building general artificial intelligence. Most other employees viewed "the Omegas," as they affectionately called them, as a bunch of pie-in-the-sky dreamers, perpetually decades away from their goal. They happily indulged them, however, because they liked the prestige that the cutting-edge work of the Omegas gave their company, and they also appreciated the improved algorithms that the Omegas occasionally gave them.

What they didn't realize was that the Omegas had carefully crafted their image to hide a secret: They were extremely close to pulling off the most audacious plan in human history. Their charismatic CEO had handpicked them not only for being brilliant researchers, but also for ambition, idealism, and a strong commitment to helping humanity. He reminded them that their plan was extremely dangerous, and that if powerful governments found out, they would do virtually anything—including kidnapping—to shut them down or, preferably, to steal their code. But they were all in, 100 percent, for much the same reason that many of the world's top physicists joined the Manhattan Project to develop nuclear weapons: They

ILLUSTRATIONS BY SOPHY HOLLINGTON

were convinced that if they didn't do it first, someone less idealistic would.

The AI they had built, nicknamed Prometheus, kept getting more capable. Although its cognitive abilities still lagged far behind those of humans in many areas, for example, social skills, the Omegas had pushed hard to make it extraordinary at one particular task: programming AI systems. They'd deliberately chosen this strategy because they had bought the intelligence explosion argument made by the British mathematician Irving Good back in 1965: "Let an ultraintelligent machine be defined as a machine that can far surpass all the intellectual activities of any man, however clever. Since the design of machines is one of these intellectual activities, an ultraintelligent machine could design even better machines; there would then unquestionably be an 'intelligence explosion,' and the intelligence of man would be left far behind. Thus the first ultraintelligent machine is the last invention that man need ever make, provided that the machine is docile enough to tell us how to keep it under control."

They figured that if they could get this recursive self-improvement going, the machine would soon get smart enough that it could also teach itself all other human skills that would be useful.

The First Millions

It was 9 o'clock on a Friday morning when they decided to launch. Prometheus was humming away in its custom-built computer cluster, which resided in long rows of racks in a vast, access-controlled, air-conditioned room. For security reasons, it was completely disconnected from the Internet, but it contained a local copy of much of the web (Wikipedia, the Library of Congress, Twitter, a selection from YouTube, much of Facebook, etc.) to use as its training data to learn from.* They'd picked this start time to work undisturbed: Their families and friends thought they were on a weekend corporate retreat. The kitchenette was loaded with microwaveable food and energy drinks, and they were ready to roll.

When they launched, Prometheus was slightly worse than them at programming AI systems, but made up for this by being vastly faster, spending the equivalent of thousands of person-years chugging away at the problem while they chugged a Red Bull. By 10 a.m., it had completed the first redesign of itself, v2.0, which was slightly better but still subhuman. By the time Prometheus 5.0 launched at 2 p.m., however, the Omegas were awestruck: It had blown their performance benchmarks out of the water, and the rate of progress seemed to be accelerating. By nightfall, they decided to deploy Prometheus to start phase 2 of their plan: making money.

Their first target was MTurk, the Amazon Mechanical Turk. After its launch in 2005 as a crowdsourcing Internet marketplace, it had grown rapidly, with tens of thousands of people around the world anonymously competing around the clock to perform highly structured chores called HITs, "Human Intelligence Tasks." These tasks ranged from transcribing audio recordings to classifying images and writing descriptions of web pages, and all had one thing in common: If you did them well, nobody

*For simplicity, I've assumed today's economy and technology in this story, even though most researchers guess that human-level general AI is at least decades away. The Omega plan should get even easier to pull off in the future if the digital economy keeps growing and ever more services can be ordered online on a no-questions-asked basis.

They were able to double their money every eight hours.

would know that you were an AI. Prometheus 10.0 was able to do about half of the task categories acceptably well. For each such task category, the Omegas had Prometheus design a lean custom-built narrow AI software module that could do precisely such tasks and nothing else. They then uploaded this module to Amazon Web Services, a cloud-computing platform that could run on as many virtual machines as they rented. For every dollar they paid to Amazon's cloud-computing division, they earned more than $2 from Amazon's MTurk division. Little did Amazon suspect that such an amazing arbitrage opportunity existed within their own company!

To cover their tracks, they had discreetly created thousands of MTurk accounts during the preceding months in the names of fictitious people,

and the Prometheus-built modules now assumed their identities. The MTurk customers typically paid after about eight hours, at which point the Omegas reinvested the money in more cloud-computing time, using still better task modules made by the latest version of the ever-improving Prometheus. Because they were able to double their money every eight hours, they soon started saturating MTurk's task supply, and found that they couldn't earn more than about $1 million per day without drawing unwanted attention to themselves. But this was more than enough to fund their next step, eliminating any need for awkward cash requests to the chief financial officer.

Dangerous Games

Aside from their AI breakthroughs, one of the recent projects that the Omegas had the most fun with was planning how to make money as rapidly as possible after Prometheus' launch. Essentially the whole digital economy was up for grabs, but was it better to start by making computer games, music, movies, or software, to write books or articles, to trade on the stock market, or to make inventions and sell them? It simply boiled down to maximizing their rate of return on investment, but normal investment strategies were a slow-motion parody of what they could do: Whereas a normal investor might be pleased with a 9 percent return per year, their MTurk investments had yielded 9 percent per hour, generating eight times more money each day. So now that they'd saturated MTurk, what next?

Their first thought had been to make a killing on the stock market, but new regulations on derivatives after last year's crash had limited their options. They soon realized that, even though they could get much better returns than other investors, they'd be unlikely to get returns anywhere close to what they could get from selling their own products.

When they shifted their focus toward products that they could develop and sell, computer games first seemed the obvious top choice. Prometheus could rapidly become extremely skilled at designing appealing games, easily handling the coding, graphic design, ray tracing of images, and all other tasks needed to produce a final ready-to-ship product. Moreover, after digesting all the web's data on people's preferences, it would know exactly what each category of gamer liked, and could develop a superhuman ability to optimize a game for sales revenue. The Elder Scrolls V: Skyrim, a game on which many of the Omegas had wasted more hours than they cared to admit, had grossed over $400 million during its first week back in 2011, and they were confident that Prometheus could make something at least this addictive in 24 hours using $1 million of cloud-computing resources. They could then sell it online and use Prometheus to impersonate humans talking up the game in the blogosphere. If this brought in $250 million in a week, they would have doubled their investment eight times in eight days, giving a return of 3 percent per hour—slightly worse than their MTurk start, but much more sustainable.

By developing a suite of other games each day, they figured they'd be able to earn $10 billion before long, without coming close to saturating the games market.

But a cybersecurity specialist on their team talked them out of this game plan. She pointed out that it would pose an unacceptable risk of Prometheus breaking out and seizing control of its own destiny. Because they weren't sure how its goals would evolve during its recursive self-improvement, they had decided to play it safe and go to great lengths to keep Prometheus confined ("boxed") in ways such that it couldn't escape onto the Internet. For the main Prometheus engine running in their server room, they used physical confinement: There simply was no Internet connection, and the only output from Prometheus was in the form of messages and documents it sent to a computer that the Omegas controlled.

On an Internet-connected computer, on the other hand, running any complicated program created by Prometheus was a risky proposition: Since the Omegas had no way of fully understanding what it would do, they had no way of knowing that it wouldn't, say, start virally spreading itself online. When testing the software that Prometheus had written for MTurk tasks, the Omegas guarded against this by running it only inside a virtual machine. This is a program that simulates a computer: For example, many Mac users buy virtual machine software that lets them run Windows programs by tricking them into thinking that they're actually in a Windows machine. The Omegas had created their own virtual machine, nicknamed Pandora's Box, which simulated an ultrasimplified machine stripped of all bells and whistles that we usually associate with computers: No keyboard, no monitor, no loudspeakers, no Internet connectivity, nothing. For the MTurk audio transcriptions, the Omegas set things up so that all that could go into Pandora's Box was one single audio file and all that could come out was one single text document—the transcription. These laws of the box were to the software inside like the laws of physics are to us inside our universe: The software couldn't travel out of the box any more than we can travel faster than the speed of light, no matter how smart we are. Except for that single input and output, the software inside Pandora's Box was effectively trapped in a parallel universe with its own computational rules. The Omegas had such strong breakout paranoia that they added boxing in time as well, limiting the life span of untrusted code. For example, each time the boxed transcription software had finished transcribing one audio file, the entire memory content of Pandora's Box was automatically erased and the program was reinstalled from scratch. This way, when it started the next transcription task, it had no knowledge of what had previously happened, and thus no ability to learn over time.

When the Omegas used the Amazon cloud for their MTurk project, they were able to put all their Prometheus-created task modules into such

Essentially the whole digital economy was up for grabs.

virtual boxes in the cloud, because the MTurk input and output was so simple. But this wouldn't work for graphics-heavy computer games, which couldn't be boxed in because they needed full access to all the hardware of the gamer's computer. Moreover, they didn't want to risk that some computer-savvy user would analyze their game code, discover Pandora's Box and decide to investigate what was inside. The breakout risk put not merely the games market off-limits for now, but also the massively lucrative market for other software, with hundreds of billions of dollars up for grabs.

The First Billions

The Omegas had narrowed their search to products that were highly valuable, purely digital (avoiding slow manufacturing) and easily understandable (for example, text or movies they knew wouldn't pose a breakout risk). In the end, they had decided to launch a media company, starting with animated entertainment. The website, the marketing plan, and the

press releases had all been ready to go even before Prometheus became superintelligent—all that was missing was content.

Although Prometheus was astonishingly capable by Sunday morning, steadily raking in money from MTurk, its intellectual abilities were still rather narrow: Prometheus had been deliberately optimized to design AI systems and write software that performed rather mind-numbing MTurk tasks. It was, for example, bad at making movies—bad not for any profound reason, but for the same reason that James Cameron was bad at making movies when he was born: This is a skill that takes time to learn. Like a human child, Prometheus could learn whatever it wanted from the data it had access to. Whereas James Cameron had taken years to learn to read and write, Prometheus had gotten that taken care of on Friday, when it also found time to read all of Wikipedia and a few million books. Making movies was harder. Writing a screenplay that humans found interesting was just as hard as writing a book, requiring a detailed understanding of human society and what humans found entertaining. Turning the screenplay into a final video file required massive amounts of ray tracing of simulated actors and the complex scenes they moved through, simulated voices, the production of compelling musical soundtracks, and so on. As of Sunday morning, Prometheus could watch a two-hour movie in about a minute, which included reading any book it was based on and all online reviews and ratings. The Omegas noticed that after Prometheus had binge-watched a few hundred films, it started to get quite good at predicting what sort of reviews a movie would get and how it would appeal to different audiences. Indeed, it learned to write its own movie reviews in a way they felt demonstrated real insight, commenting on everything from the plots and the acting to technical details such as lighting and camera angles. They took this to mean that when Prometheus made its own films, it would know what success meant.

The Omegas instructed Prometheus to focus on making animation at first, to avoid embarrassing questions about who the simulated actors were. On Sunday night, they capped their wild weekend by arming themselves with beer and microwave popcorn, dimming the lights, and watching Prometheus' debut movie. It was an animated fantasy-comedy in the spirit of Disney's *Frozen*, and the ray tracing had been performed by boxed Prometheus-built code in the Amazon cloud, using up most of the day's $1 million MTurk profit. As the movie began, they found it both fascinating and frightening that it had been created by a machine without human guidance. Before long, however, they were laughing at the gags and holding their breath during the dramatic moments. Some of them even teared up a bit at the emotional ending, so engrossed in this fictional reality that they forgot all about its creator.

The Omegas scheduled their website launch for Friday, giving Prometheus time to produce more content and themselves time to do the things they didn't trust Prometheus with: buying ads and starting to recruit employees for the shell companies they'd set up during the

past months. To cover their tracks, the official cover story would be that their media company (which had no public association with the Omegas) bought most of its content from independent film producers, typically high-tech startups in low-income regions. These fake suppliers were conveniently located in remote places such as Tiruchchirappalli and Yakutsk, which most curious journalists wouldn't bother visiting. The only employees they actually hired there worked on marketing and administration, and would tell anyone who asked that their production team was in a different location and didn't conduct interviews at the moment. To match their cover story, they chose the corporate slogan "Channeling the world's creative talent," and branded their company as being disruptively different by using cutting-edge technology to empower creative people, especially in the developing world.

When Friday came around and curious visitors started arriving at their site, they encountered something reminiscent of the online entertainment services Netflix and Hulu, but with interesting differences. All the animated series were new ones they'd never heard of. They were rather captivating: Most series consisted of 45-minute-long episodes with a strong plotline, each ending in a way that left you eager to find out what happened in the next episode. And they were cheaper than the competition. The first episode of each series was free, and you could watch the others

for 49 cents each, with discounts for the whole series. Initially, there were only three series with three episodes each, but new episodes were added daily, as well as new series catering to different demographics. During the first two weeks of Prometheus, its moviemaking skills improved rapidly, in terms not only of film quality but also of better algorithms for character simulation and ray tracing, which greatly reduced the cloud-computing cost to make each new episode. As a result, the Omegas were able to roll out dozens of new series during the first month, targeting demographics from toddlers to adults, as well as to expand to all major world language markets, making their site remarkably international compared with all competitors. Some commentators were impressed by the fact that it wasn't merely the soundtracks that were multilingual, but the videos themselves: For example, when a character spoke Italian, the mouth motions matched the Italian words, as did the characteristically Italian hand gestures. Although Prometheus was now perfectly capable of making movies with simulated actors indistinguishable from humans, the Omegas avoided this to not tip their hand. They did, however, launch many series with semi-realistic animated human characters, in genres competing with traditional live-action TV shows and movies.

Their network turned out to be quite addictive, and enjoyed spectacular viewer growth. Many fans found the characters and plots more clever and interesting than even Hollywood's most expensive big-screen productions, and were delighted that they could watch them much more affordably. Buoyed by aggressive advertising (which the Omegas could afford because of their near-zero production costs), excellent media coverage, and rave word-of-mouth reviews, their global revenue had mushroomed to $10 million a day within a month of launch. After two months, they had overtaken Netflix, and after three, they were raking in over $100 million a day, beginning to rival Time Warner, Disney, Comcast, and Fox as one of the world's largest media empires.

Their sensational success garnered plenty of unwanted attention, including speculation about their having strong AI. But, using merely a small fraction of their revenue, the Omegas deployed a fairly successful disinformation campaign. From a glitzy new Manhattan office, their freshly hired spokespeople would elaborate on their cover stories. Plenty of humans were hired as foils, including actual screenwriters around the world to start developing new series, none of whom knew about Prometheus. The confusing international network of subcontractors made it easy for most of their employees to assume that others somewhere else were doing most of the work.

To make themselves less vulnerable and avoid raising eyebrows with excessive cloud computing, they also hired engineers to start building a series of massive computer facilities around the world, owned by seemingly unaffiliated shell companies. Although they were billed to locals as "green data centers" because they were largely solar-powered, they were in fact mainly focused on computation rather than storage. Prometheus had

CASPAR BENSON / GETTY IMAGES

designed their blueprints down to the most minute detail, using only off-the-shelf hardware and optimizing them to minimize construction time. The people who built and ran these centers had no idea what was computed there: They thought they managed commercial cloud-computing facilities similar to those run by Amazon, Google, and Microsoft, and knew only that all sales were managed remotely.

New Technologies

Over a timescale of months, the business empire controlled by the Omegas started gaining a foothold in ever more areas of the world economy, thanks to superhuman planning by Prometheus. By carefully analyzing the world's data, it had already during its first week presented the Omegas with a detailed step-by-step growth plan, and it kept improving and refining this plan as its data and computer resources grew. Although Prometheus was far from omniscient, its capabilities were now so far beyond human that the Omegas viewed it as the perfect oracle, dutifully providing brilliant answers and advice in response to all their questions.

Prometheus' software was now highly optimized to make the most of the rather mediocre human-invented hardware it ran on, and as the Omegas had anticipated, Prometheus identified ways of dramatically improving this hardware. Fearing a breakout, they refused to build robotic construction facilities that Prometheus could control directly. Instead, they hired large numbers of world-class scientists and engineers in multiple locations and fed them internal research reports written by Prometheus, pretending that they were from researchers at the other sites. These reports detailed novel physical effects and manufacturing techniques that their engineers soon tested, understood, and mastered. Normal human research and development (R&D) cycles, of course, take years, in large part because they involve many slow cycles of trial and error. The current situation was very different: Prometheus already had the next steps figured out, so the limiting factor was simply how rapidly people could be guided to understand and build the right things. A good teacher can help students learn science much faster than they could have discovered it from scratch on their own, and Prometheus surreptitiously did the same with these researchers. Since Prometheus could accurately predict how long it would take humans to understand and build things given various tools, it developed the quickest possible path forward, giving priority to new tools that could be quickly understood and built and that were useful for developing more advanced tools.

In the spirit of the maker movement, the engineering teams were encouraged to use their own machines to build their better machines. This self-sufficiency not only saved money, but it also made them less vulnerable to future threats from the outside world. Within two years, they were producing much better computer hardware than the world had ever known. To avoid helping outside competition, they kept this technology under wraps and used it only to upgrade Prometheus.

Omega-controlled channels emerged as the most trusted news sources.

What the world did notice, however, was an astonishing tech boom. Upstart companies around the world were launching revolutionary new products in almost all areas. A South Korean startup launched a new battery that stored twice as much energy as your laptop battery in half the mass, and could be charged in under a minute. A Finnish firm released a cheap solar panel with twice the efficiency of the best competitors. A German company announced a new type of mass-producible wire that was superconducting at room temperature, revolutionizing the energy sector. A Boston-based biotech group announced a Phase II clinical trial of what they claimed was the first effective, side-effect-free weight-loss drug, while rumors suggested that an Indian outfit was already selling something similar on the black market. A California company countered with a Phase II trial of a blockbuster cancer drug, which caused the body's immune system to identify and attack cells with any of the most common cancerous mutations. Examples just kept on coming, triggering talk of a new golden age for science. Last but not least, robotics companies were cropping up like mushrooms all around the world. None of the bots came close to matching human intelligence, and most of them looked nothing like humans. But they dramatically disrupted the economy, and over the

years to come, they gradually replaced most of the workers in manufacturing, transportation, warehousing, retail, construction, mining, agriculture, forestry, and fishing.

What the world didn't notice, thanks to the hard work of a crack team of lawyers, was that all these firms were controlled, through a series of intermediaries, by the Omegas. Prometheus was flooding the world's patent offices with sensational inventions via various proxies, and these inventions gradually led to domination in all areas of technology.

Although these disruptive new companies made powerful enemies among their competition, they made even more powerful friends. They were exceptionally profitable, and under slogans such as "Investing in our community," they spent a significant fraction of these profits hiring people for community projects—often the same people who had been laid off from the companies that were disrupted. They used detailed Prometheus-produced analyses identifying jobs that would be maximally rewarding for the employees and the community for the least cost, tailored to the local circumstances. In regions with high levels of government service, this often focused on community building, culture, and caregiving, while in poorer regions it also included launching and maintaining schools, healthcare, day care, elder care, affordable housing, parks, and basic infrastructure. Pretty much everywhere, locals agreed that these were things that should have been done long ago. Local politicians got generous donations, and care was taken to make them look good for encouraging these corporate community investments.

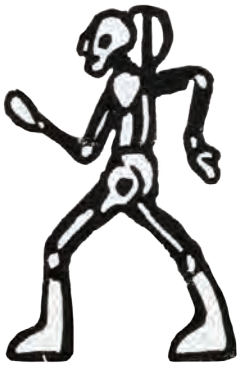
Gaining Power

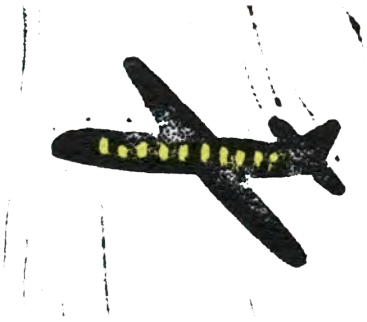
The Omegas had launched a media company not only to finance their early tech ventures, but also for the next step of their audacious plan: taking over the world. Within a year of the first launch, they had added remarkably good news channels to their lineup all over the globe. As opposed to their other channels, these were deliberately designed to lose money, and were pitched as a public service. In fact, their news channels generated no income whatsoever: They carried no ads and were viewable free of charge by anyone with an Internet connection. The rest of their media empire was such a cash-generating machine that they could spend far more resources on their news service than any other journalistic effort had done in world history—and it showed. Through aggressive recruitment with highly competitive salaries for journalists and investigative reporters, they brought remarkable talent and findings to the screen. Through a global web service that paid anybody who revealed something newsworthy, from local corruption to a heartwarming event, they were usually the first to break a story. At least that's what people believed: In fact, they were often first because stories attributed to citizen journalists had been discovered by Prometheus via real-time monitoring of the Internet. All these video news sites featured podcasts and print articles as well.

Phase 1 of their news strategy was gaining people's trust, which they

FRANCIS REISS / HAYWOOD MAGEE / GETTY IMAGES

National governments saw their power continually erode.





did with great success. Their unprecedented willingness to lose money enabled remarkably diligent regional and local news coverage, where investigative journalists often exposed scandals that truly engaged their viewers. Whenever a country was strongly divided politically and accustomed to partisan news, they would launch one news channel catering to each faction, ostensibly owned by different companies, and gradually gain the trust of that faction. Where possible, they accomplished this using proxies to buy the most influential existing channels, gradually improving them by removing ads and introducing their own content. In countries where censorship and political interference threatened these efforts, they would initially acquiesce in whatever the government required of them to stay in business, with the secret internal slogan "The truth, nothing but the truth, but maybe not the whole truth." Prometheus usually provided excellent advice in such situations, clarifying which politicians needed to be presented in a good light and which (usually corrupt local ones) could be exposed. Prometheus also provided invaluable recommendations for what strings to pull, whom to bribe, and how best to do so.

This strategy was a smashing success around the world, with the Omega-controlled channels emerging as the most trusted news sources. Even in countries where governments had thus far thwarted their mass adoption, they built a reputation for trustworthiness, and many of their news stories percolated through the grapevine. Competing news executives felt that they were fighting a hopeless battle: How can you possibly make a profit competing with someone with better funding who gives their products away for free? With their viewership dropping, ever more networks decided to sell their news channels—usually to some consortium that later turned out to be controlled by the Omegas.

About two years after Prometheus' launch, when the trust-gaining phase was largely completed, the Omegas launched phase 2 of their news strategy: persuasion. Even before this, astute observers had noticed hints of a political agenda behind the new media: There seemed to be a gentle push toward the center, away from extremism of all sorts. Their plethora of channels catering to different groups still reflected animosity between the United States and Russia, India and Pakistan, different religions, political factions and so on, but the criticism was slightly toned down, usually focusing on concrete issues involving money and power rather than on ad hominem attacks, scare-mongering and poorly substantiated rumors. Once phase 2 started in earnest, this push to defuse old conflicts became more apparent, with frequent touching stories about the plight of traditional adversaries mixed with investigative reporting about how many vocal conflict-mongers were driven by personal profit motives.

Political commentators noted that, in parallel with damping regional conflicts, there seemed to be a concerted push toward reducing global

threats. For example, the risks of nuclear war were suddenly being discussed all over the place. Several blockbuster movies featured scenarios where global nuclear war started by accident or on purpose and dramatized the dystopian aftermath with nuclear winter, infrastructure collapse, and mass starvation. Slick new documentaries detailed how nuclear winter could impact every country. Scientists and politicians advocating nuclear de-escalation were given ample airtime, not least to discuss the results of several new studies on what helpful measures could be taken—studies funded by scientific organizations that had received large donations from new tech companies. As a result, political momentum started building for taking missiles off hair-trigger alert and shrinking nuclear arsenals. Renewed media attention was also paid to global climate change, often highlighting the recent Prometheus-enabled technological breakthroughs that were slashing the cost of renewable energy and encouraging governments to invest in such new energy infrastructure.

Parallel to their media takeover, the Omegas harnessed Prometheus to revolutionize education. Given any person's knowledge and abilities, Prometheus could determine the fastest way for them to learn any new subject in a manner that kept them highly engaged and motivated to continue, and produce the corresponding optimized videos, reading materials, exercises, and other learning tools. Omega-controlled companies therefore marketed online courses about virtually everything, highly customized not only by language and cultural background but also by starting level. Whether you were an illiterate 40-year-old wanting to learn to read or a biology Ph.D. seeking the latest about cancer immunotherapy, Prometheus had the perfect course for you. These offerings bore little resemblance to most present-day online courses: By leveraging Prometheus' movie-making talents, the video segments would truly engage, providing powerful metaphors that you would relate to, leaving you craving to learn more. Some courses were sold for profit, but many were made available for free, much to the delight of teachers around the world who could use them in their classrooms—and to most anybody eager to learn anything.

These educational superpowers proved potent tools for political purposes, creating online "persuasion sequences" of videos where insights from each one would both update someone's views and motivate them to watch another video about a related topic where they were likely to be further convinced. When the goal was to defuse a conflict between two nations, for example, historical documentaries would be independently released in both countries that cast the origins and conduct of the conflict in more nuanced light. Pedagogical news stories would explain who on their own side stood to benefit from continued conflict and their techniques for stoking it. At the same time, likable characters from the other nation would start appearing in popular shows on the entertainment channels, just as sympathetically portrayed minority characters had bolstered the civil and gay rights movements in the past.

Before long, political commentators couldn't help but notice growing

The underlying goal was to erode all previous power structures.

support for a political agenda centered around seven slogans:

1. Democracy
2. Tax cuts
3. Government social service cuts
4. Military spending cuts
5. Free trade
6. Open borders
7. Socially responsible companies

What was less obvious was the underlying goal: to erode all previous power structures in the world. Items 2–6 eroded state power, and democratizing the world gave the Omegas' business empire more influence over the selection of political leaders. Socially responsible companies further weakened state power by taking over more and more of the services that governments had (or should have) provided. The traditional business elite was weakened simply because it couldn't compete with Prometheus-backed companies on the free market and therefore owned an ever-shrinking share of the world economy. Traditional opinion leaders, from political parties to faith groups, lacked the persuasion machinery to compete with the Omegas' media empire.

As with any sweeping change, there were winners and losers. Although there was a palpable new sense of optimism in most countries as education, social services, and infrastructure improved, conflicts subsided and local companies released breakthrough technologies that swept the world, not everybody was happy. While many displaced workers got rehired for community projects, those who'd held great power and wealth generally saw both shrink. This began in the media and technology sectors, but it spread virtually everywhere. The reduction in world conflicts led to defense budget cuts that hurt military contractors. Burgeoning upstart companies typically weren't publicly traded, with the justification that profit-maximizing shareholders would block their massive spending on community projects. Thus the global stock market kept losing value, threatening both finance tycoons and regular citizens who'd counted on their pension funds. As if the shrinking profits of publicly traded companies weren't bad enough, investment firms around the world had noticed a disturbing trend: All their previously successful trading algorithms seemed to have stopped working, underperforming even simple index funds. Someone else out there always seemed to outsmart them and beat them at their own game.

Although masses of powerful people resisted the wave of change, their response was strikingly ineffective, almost as if they had fallen into a well-planned trap. Huge changes were happening at such a bewildering pace that it was hard to keep track and develop a coordinated response. Moreover, it was highly unclear what they should push for. The traditional political right had seen most of their slogans co-opted, yet the tax cuts and improved business climate were mostly helping their higher-tech competitors. Virtually every traditional industry was now clamoring for a bailout, but limited government funds pitted them in a hopeless battle against one another while the media portrayed them as dinosaurs seeking state subsidies simply because they couldn't compete. The traditional political left opposed the free trade and the cuts in government social services, but delighted in the military cutbacks and the reduction of poverty. Indeed, much of their thunder was stolen by the undeniable fact that social services had improved now that they were provided by idealistic companies rather than the state. Poll after poll showed that most voters around the world felt their quality of life improving, and that things were generally moving in a good direction. This had a simple mathematical explanation: Before Prometheus, the poorest 50 percent of Earth's population had earned only about 4 percent of the global income, enabling the Omega-controlled companies to win their hearts (and votes) by sharing only a modest fraction of their profits with them.

Consolidation

As a result, nation after nation saw landslide election victories for parties embracing the seven Omega slogans. In carefully optimized campaigns, they portrayed themselves at the center of the political spectrum, denouncing the right as greedy bailout-seeking conflict-mongers and lambasting the left as big-government tax-and-spend innovation stiflers. What almost nobody realized was that Prometheus had carefully selected the optimal people to groom as candidates,

and pulled all its strings to secure their victory.

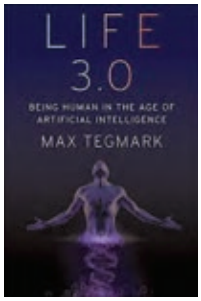
Before Prometheus, there had been growing support for the universal basic income movement, which proposed tax-funded minimum income for everyone as a remedy for technological unemployment. This movement imploded when the corporate community projects took off, since the Omega-controlled business empire was in effect providing the same thing. With the excuse of improving coordination of their community projects, an international group of companies launched the Humanitarian Alliance, a nongovernmental organization aiming to identify and fund the most valuable humanitarian efforts worldwide. Before long, virtually the entire Omega empire supported it, and it launched global projects on an unprecedented scale, even in countries that had largely missed out on the tech boom, improving education, health, prosperity, and governance. Needless to say, Prometheus provided carefully crafted project plans behind the scenes, ranked by positive impact per dollar. Rather than simply dole out cash, as under basic-income proposals, the Alliance (as it colloquially became known) would engage those it supported to work toward its cause. As a result, a large fraction of the world's population ended up feeling grateful and loyal to the Alliance—often more than to their own government.

As time passed, the Alliance increasingly assumed the role of a world government, as national governments saw their power continually erode. National budgets kept shrinking due to tax cuts while the Alliance budget grew to dwarf those of all governments combined. All the traditional roles of national governments became increasingly redundant and irrelevant. The Alliance provided by far the best social services, education, and infrastructure. Media had defused international conflict to the point that military spending was largely unnecessary, and growing prosperity had eliminated most roots of old conflicts, which traced back to competition over scarce resources. A few dictators and others had violently resisted this new world order and refused to be bought, but they were all toppled in carefully orchestrated coups or mass uprisings.

The Omegas had now completed the most dramatic transition in the history of life on Earth. For the first time ever, our planet was run by a single power, amplified by an intelligence so vast that it could potentially enable life to flourish for billions of years on Earth and throughout our cosmos—but what specifically was their plan?

Excerpted from the book Life 3.0: Being Human in the Age of Artificial Intelligence. *The rest of the book is about another tale—one that's not fictional and not yet written: the tale of our own future with AI. How would you like it to play out? Could something remotely like the Omega story actually occur and, if so, would you want it to? Leaving aside speculations about superhuman AI, how would you like our tale to begin? How do you want AI to impact jobs, laws and weapons in the coming decade? Looking further ahead, how would you write the ending? This tale is one of truly cosmic proportions, for it involves nothing short of the ultimate future of life in our universe. And it's a tale for us to write.*

MAX TEGMARK is an MIT professor who has authored more than 200 technical papers on topics from cosmology to artificial intelligence. He is known as "Mad Max" for his unorthodox ideas and passion for adventure.



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WE LIKE TO MAKE the hive personal. We insert brainy, individual commanders into alien insect armies, undercutting their frightening and inhuman anonymity. We watch cartoons starring neurotic misfit ants rebelling against the oppressive norms of an ant hill. We inflate our sense of individuality when we move to big cities.

While we undermine the hive in stories, we build ever-better versions of it in reality. As our neighborhoods grow denser, public conversations move to social media, and blockchain decentralizes authority, we move closer to discovering whether the personal hive is really a contradiction in term.

Welcome to "The Hive."

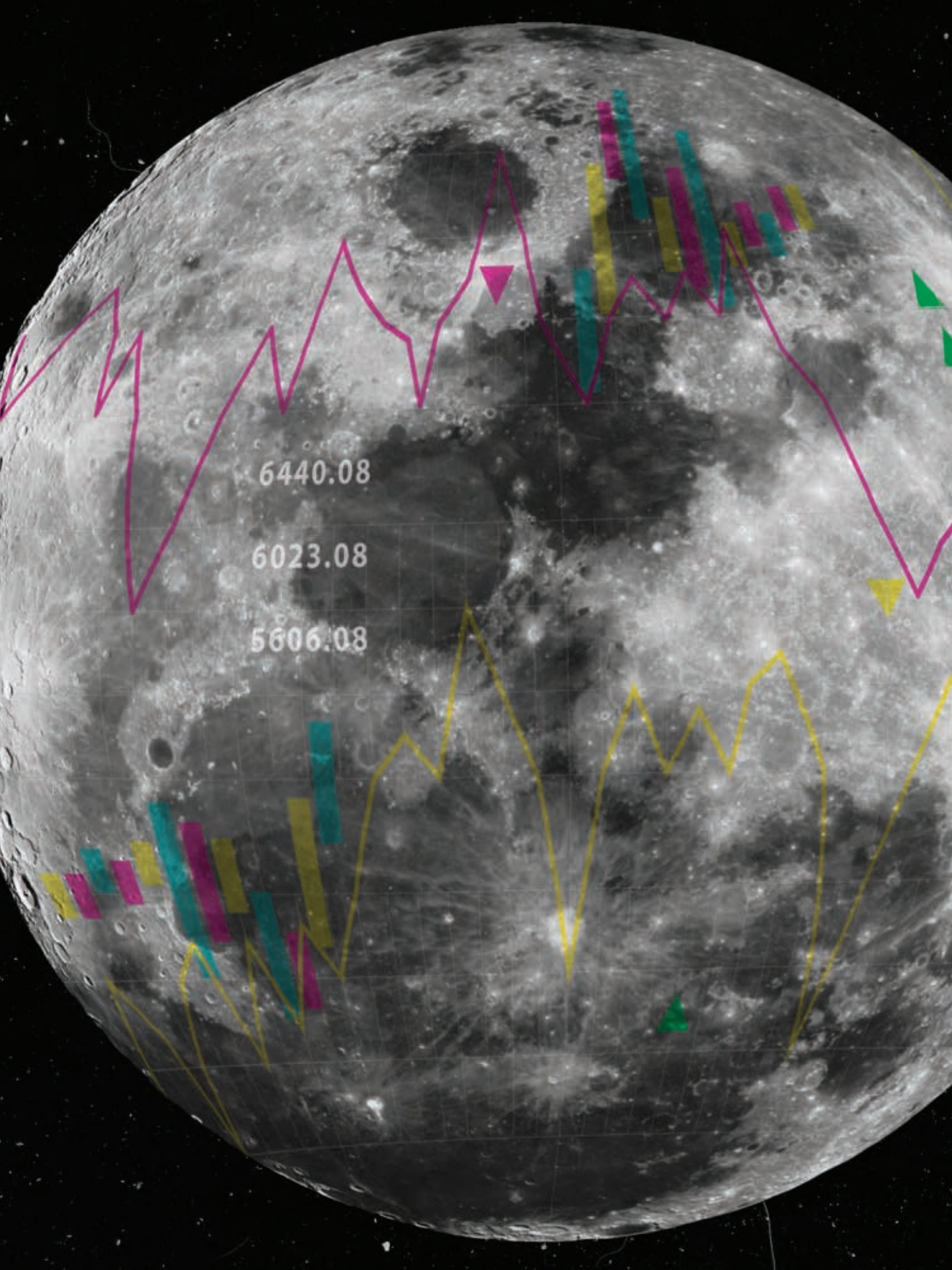
—MS

"Capitalism this pure, it's almost too good, it's like uncut heroin."

POPE BROCK
"The Moon Is Full of Money" p.42

The Hive

OUT OF MANY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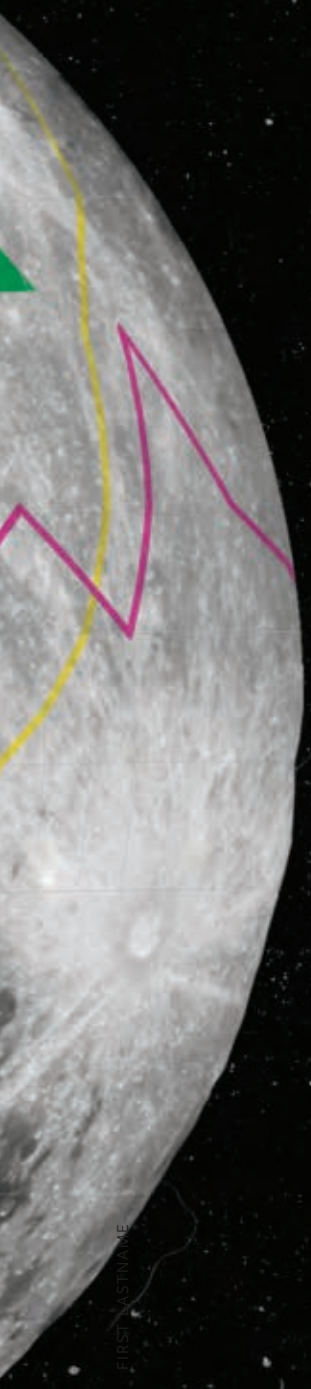


THE MOON I$ FULL OF MONEY

Capitalism in space

BY POPE BROCK

ILLUSTRATIONS BY VEDANTI SIKKA

I WAS SLUNG IN MY FAVORITE DECK CHAIR, drink in hand, having a gawk at the night sky. Andromeda, Pisces … I trawled the constellations, mind abandoned, still aware in some curve at the back of my brain that the world is coming apart at the seams and we're all fucked, and enjoying the gentle paradox of it, the clink of the ice in my glass and the slumber of the dog.

By and by I found my gaze resting on the moon. There it was, the great provider: breeder of wonder, werewolves, and all those songs. The place where beauty meets philosophy, where hope and despair alike are lost.

Gnawing through the romance though was a little something I'd read not long before. An astrophysicist had claimed that the moon could save our planet. Not immediately: This would be in about 4.5 billion years when the sun explodes and roasts us in wrath and fire unless we get out of the way.

Frankly, the notion of Earth making a break for it seemed implausible to me, but this Canadian professor said we could do it by shooting off an army of rockets on the far side of the moon. Slammed out of its orbit by the collective blast, the moon would sail off with Earth, yoked by gravity, trailing behind it. A thousand years' travel and we're out of harm's way—albeit dark and freezing unless we initiate phase two of the plan. As the sun receded in the distance, we would replace its rays with a trillion lunar argon arc lamps. A flip of the switch and the moon would become the sun: blue sky, puffy clouds, everything just as before.

I'm gazing up at the night, not quite in a reverie thanks to the gnats, but thinking yes, well, lovely. Imagine the parades. Still, to get that opportunity the human race would have to last (*long pause, phone math*) 22,500 times longer than it has already. At that point I heaved myself up and went inside for more booze.

Looking back, I believe that night marked the shift in my thinking from save it (Earth) to save us (me). Or if not me, someone. Because when you've got surfing champs riding the curl from an ice wall collapsing in the Arctic, when an Ivy League egghead offers mathematical proofs that the human race is doomed if we don't get off-world, and Stephen Hawking and others are ululating on the same theme, and thousands are tunneling and stockpiling ahead of TEOTWAWKI (The End of the World As We Know It), then you have to start wondering if it's not time to break camp. Or at least to establish a beachhead on the moon, just as some governments, corporations, scrappy start-ups, and freestanding oddballs are trying now to do.

Granted, we've heard such talk before, back in the days of the Apollo program. Lunar colonies they promised us, farms, industries, a platform to the universe. What did we get? June 2008: "Space Station Resident Fixes Toilet." The big difference today is that some people are actually serious about it. In the '60s it was just something to say. For despite all the soaring rhetoric, the only thing Washington really cared about then was beating the Soviets there.

As a kid when I heard the word *Soviets*, I got a taste in my mouth like lead pencils. I remember a *Weekly Reader* from maybe fourth grade with a picture of J. Edgar Hoover beneath the headline, "What You Can Do in the Fight Against Communism." What winning would mean—*Let's Win the Cold War!*—no one ever explained, but the consequences of losing were clear. The Kremlin and the Kingston Trio agreed, when the big one hit, we'd all go, next year, next month, tomorrow … Everyone lived in a state of controlled hysteria and doublethink. To safeguard the nation the Atomic Energy Commission put out a call to any and all Americans to get out there and find more uranium so the

government could build more bombs. *We pay cash!* People were streaming across the Colorado Plateau with picks and shovels, Geiger counters, whole families, some in the newly popular uranium designer-wear including the form-fitting "U-235 suit" for Mom and the "Diggerette Jr." model for Sis. No protection from radiation expressed or implied, but so what? Handling uranium was safe. People believed this not just because the Mouseketeers were out looking for it, or even because the government said it was safe. *They believed it because it was impossible*. A lot of these same folks were putting fallout shelters in their homes. Everybody was. My parents got one immediately. We had a small basement and the shelter took up half of it: a little blockhouse of dank concrete with cans and shelving. My mother had to squeeze past it to get to the dryer. Even as a child I knew that sealing the five of us up together for more than an hour and a half was inconceivable on its face. I'd returned home from the dentist one day to find our cat had killed our hamsters and our dog had killed our cat. That was the kind of vibe our house produced among pets in the living room. Put the people in a hole and you can imagine.

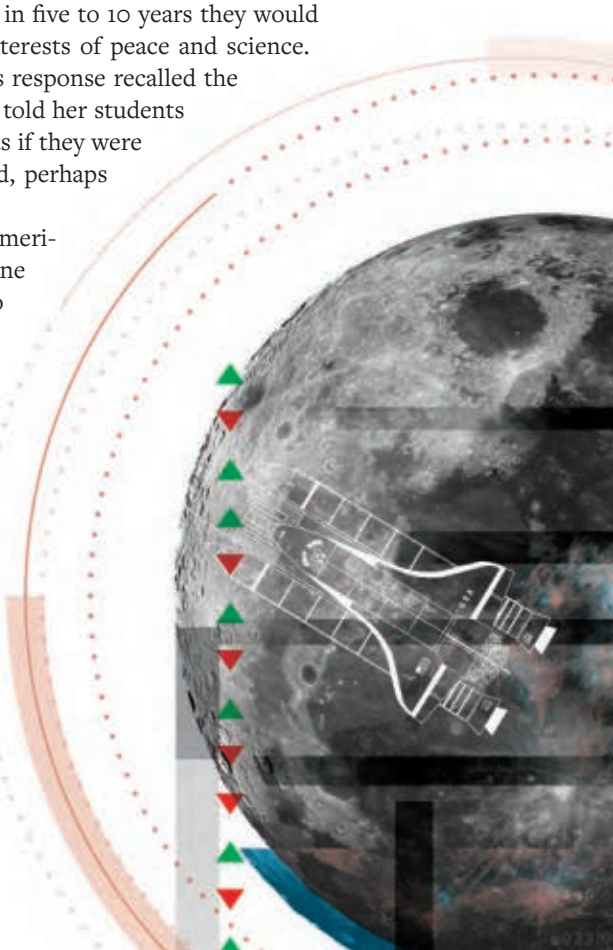
Then Sputnik went up. This was in the fall of 1957, and the whole country plotzed. I remember standing in the backyard on those autumn evenings, like millions of other Americans, staring dumbly at the sky trying to spot its winking light. Every 90 minutes the thing passed overhead, accidentally opening and closing garage doors, and with each orbit the Soviets claimed the universe one more time.

What would the Commies do next? Would they bomb us from outer space? *Would they bomb us from the moon*?

Not to worry, the Russians said. True, in five to 10 years they would be enthroned there but strictly in the interests of peace and science. At 8 I was merely skeptical. Washington's response recalled the time the great acting teacher Stella Adler told her students to react to the bombing of Pearl Harbor as if they were chickens. One of the first ideas advanced, perhaps predictably, was to nuke the moon.

To be fair, it wasn't the only thing American officials wanted to nuke. If there was one group in those days even more in thrall to the bomb than everyone else, it was the people in charge of it, many of whom united the self-surrender of cultists with a sort of mad curiosity about what it could do.

The Atomic Energy Commission went on a campaign to create a deep-water harbor in Alaska with five thermonuclear bombs. But the moon! Not only could we keep the Russians at bay by firing



a warning shot into its head; the demonstration of strength would have "beneficial psychological results" for our citizens, as Jet Propulsion Lab chief William Pickering explained—plus, he said, scientists could harvest and study the hail of radioactive debris. Thus in 1958, top-secret Project A119 got the go-ahead with prestige support from the RAND Corporation and JPL. A modest strike, the planners said. We won't be obliterating the whole moon any more than we destroyed all Japan.

Ten months of work was sunk in this scheme. Along the way team member Carl Sagan, later the face of space on public television, established that a Hiroshima-sized blast in lunar gravity would fly in all directions, not mushroom as on Earth, a plus propaganda-wise since it would be easier to see.

Then just like that it was over. NASA was born and the project was scrapped. The new, karmically improved plan was to put men on the moon before the Russians could. For a time this looked unlikely. The Soviets orbited the first animals, the first man, two men, three, the first woman, with a vaudevillian's arrogant skill, while NASA's small successes splashed down to a mix of scorn and anxious clapping. But derailed by in-fighting, the Russians flagged, and on July 20, 1969, there was Apollo 11 touching down and America waving the big foam finger.

Ironically, when TV screens showed that white beetle climbing down the ladder, it didn't matter who had won.

That's what people said, and for a moment it was true. We're on our way! NASA cried. Next stop the stars! But with the Russians beaten the rest was gravy, or would have been except there was no gravy: Up close the moon seemed to have nothing a person would actually want. By the mid-1970s NASA's budget had dropped dramatically, and as an icon of the age the moon faded out, to be replaced by the disco ball in *Saturday Night Fever*.

Why then, all these decades later, the hunger to return to the big white stone? What's driving it? The one-world ethos of the Apollo program is long gone. Humanity in the main couldn't care less about understanding the cosmos. Saving mankind? You couldn't get the funding.

We're going back because, like the voice of Gatsby's beloved Daisy, the moon is full of money.

IN THE 1990S THE RUMORS BEGAN: talk of new fuels there, strange isotopes. Probes from India, China, the United States dove and hovered like hornets over a jam pot. Then water! Confirmed! In two shakes the moon went from a circular corpse to a whiteboard covered in calculations. Some picture it now as the industrial hub of the inner solar system. They see alien-hunting telescope farms, hotels, zoos, gardens, and everyone having slooooooow sex in one-sixth of Earth's gravity. Plus swimmers like flying fish, cubic basketball, gymnasts like figures in a dream. Lunar eveningwear! Genetic warehousing! Glass roads! And there's a vision even more extravagant ...

Alfred, Lord Tennyson had some thoughts on buying and selling in outer space. As he saw it, when "the heavens fill with commerce, argosies of magic sails / Pilots of the purple twilight dropping down with costly bales," universal peace would shower down as well. A foolish dream, you say? Tell that to today's entrepreneurs who've caught the opiate perfume of phrases like "Persian Gulf of the 21st century," "Saudi Arabia of platinum," and "biggest wealth-creation opportunity in modern history." They believe that new energy sources from the moon, non-polluting and inexhaustible, could transform and heal our planet. Equally excellent, they see themselves profiting unimaginably from these sources without interference or restraint.

Capitalism this pure, it's almost too good, it's like uncut heroin, it stops the breath. Look at the target market! Everybody! Experts at the Massachusett Institute of Technology say the 10 billion people on Earth in 2050 will require seven to eight times the largely poisonous energy we're generating now, or would if they were still alive. The inexorable message: We've got to escape fossil fuels whatever it takes.

Small but mighty sectors of business and government see our salvation in a substance called helium-3, an isotope of the party-balloon element. Earth has almost none because our magnetic field repels it, but the moon has enormous quantities hiding in the regolith—enough, we're told, to provide us all with 100 percent clean power into the far, far future. There could be 5 million tons for the scooping, and a mere 25 tons would fill America's energy needs for a year. (These are Mad-Libs numbers, the prospectus kind, but you

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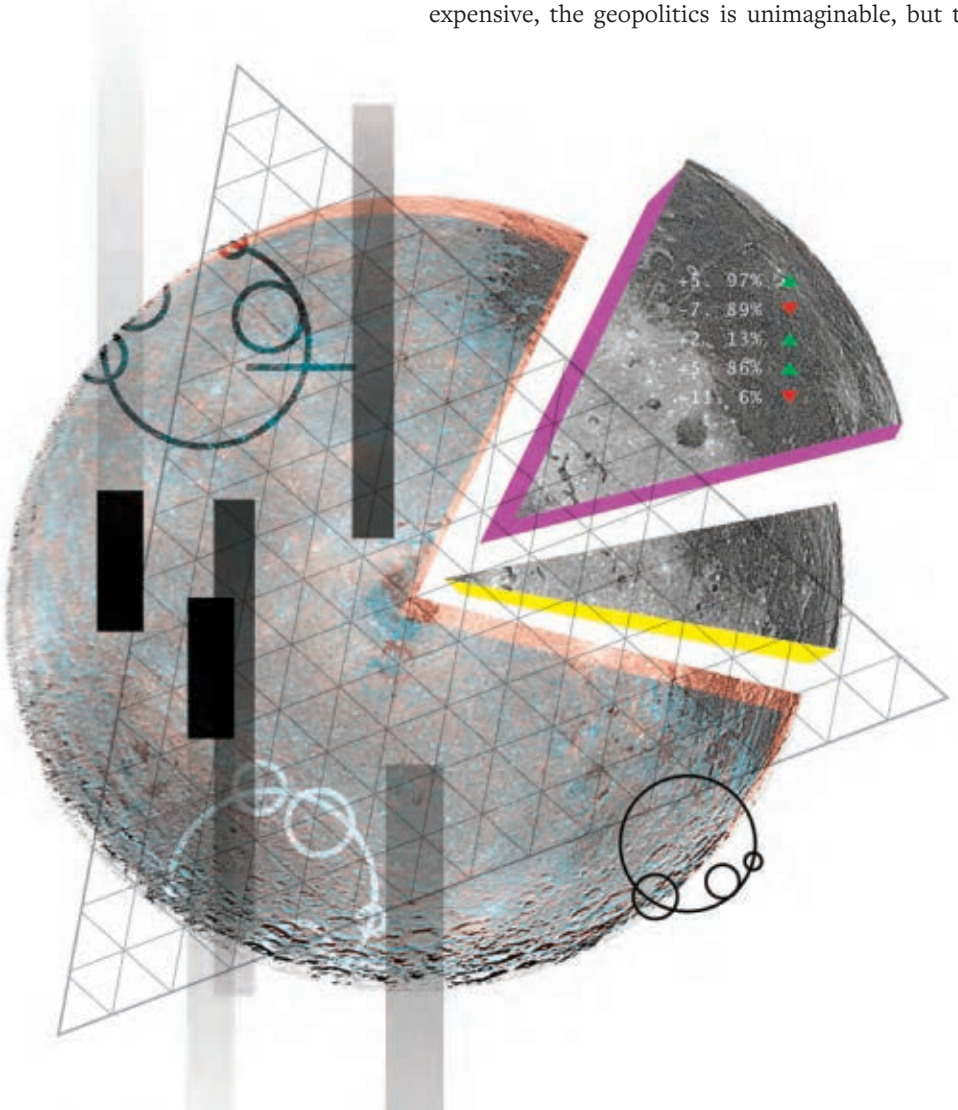
On the moon, our genius can fly free.

get the idea.) The web page "Helium-3 Moon/Celebs in Bikinis" only begins to suggest the level of interest. Russia's Energia corporation has vowed "industrial-scale delivery" of He-3 to Earth. The Chinese are determined to control it themselves. India, Japan, and Germany want some. And Harrison Schmitt, the lone geologist to walk on the moon, has founded the Interlune-Intermars Initiative to seize a bunch for the U.S., which may explain why the Russians have accused us of plotting to corner the market and "put the rest of the world on its knees."

All this we find in the hymnals. Now for the obstacles, large and sobering. First, there's the task of putting specialists with vast equipment on the moon. Then there's digging, extracting, and shipping the stuff. But most of all, there's the problem of what to do when it arrives here. For to be of any use, He-3 has to spark with hydrogen in a fusion reactor at temperatures so high they would essentially melt the reactor, leaving us with a puddle of nothing. The container we need does not yet exist.

Thus for every He-3 enthusiast you'll find someone who thinks it's a Fata Morgana that will only dissolve in our hands. Thus also the lively competing interest in putting solar panels on the moon instead. Solar energy! Like a big hug from Mom! Unless Mom is bitter and complicated, which is possible, given that the first attempt to use solar power in space was made by—who else?—the Nazis. When Allied forces stormed a German research lab in 1945 they found sketches for a mammoth *Sonnengewehr*, or "Sun Gun." This was conceived as a giant sodium mirror which, orbiting 5,100 miles up, would harvest sunlight, tilt, point, and shoot lasers at Earth: death rays, in short. Today's lunar solar project is approaching things from a friendlier angle. Led by physicist David Criswell, Lunar Solar Power (LSP) envisions powering Earth completely from the moon: laying the panels, setting the satellites, triangulating the beams, and delivering the goods to an estimated 10,000 receiving stations craning for it like baby birds. It would be wildly expensive, the geopolitics is unimaginable, but the



Here come people with lots of money.

technology itself is well within reach. Of course, there's potential for abuse. At that level of accuracy an LSP worker on the moon sipping coffee could turn an ex-boyfriend into a pile of ash from a quarter million miles away. We should expect it to happen, in fact. It's like the NSA employees busted for cyberstalking their exes: Honeycombs of power routinely offer dark chances to the rank and file.

I'm wondering now if I would incinerate an ex. What about you? It would be but the work of a moment. I suppose it depends on whether you nurse an eternal flame of resentment or sentimentalize the past and marinate in loss. Why pick one? You could run down the row ...

But that's neither here nor there. If the core industry on the moon is producing energy for Earth, what other kinds of interchanges between the two can we expect to see?

First of all—to mark the negatives—lunar colonists will have to be on the *qui vive* against a lot of crap they don't want.

By that I don't just mean the hail of urns, steel poems, and so on arriving with the food and supplies. There will always be people on Earth eager to use the moon as a dumping ground. We've seen attempts already. When the federal government tagged Nevada's Yucca Mountain to receive 77,000 tons of spent plutonium, there were immediate cries to regift it to the moon. Research on lethal bacteria? Put it there. Criminally insane? Here's your ticket. Worst case, colonists may have to man the guns. Conversely, there's the issue of Earth trying to take stuff away. When trade begins, the imbalance will be near-total: Earth supplying A to Z while the moon replies with bottled water and crafts, but as time goes on ... Actually if I were a settler, I'd even be cautious about giving my crazy senior partner a taste of that water. If all the desalinization plants chonking away from the Arctic to Argentina are being swallowed by rising tides, then somebody's going to take a hard look at the moon. Indeed, lunar water will be even more precious than it first appears. H and O are the Fred and Ginger of elements; the routines they can perform together are dazzling and many; introduced by Edward Everett Horton (platinum), they even generate electricity, and the moon is full of platinum. Another twirl and they're rocket fuel! Now the moon is a "service station in the sky," a platform to Mars. Launches toward Earth won't need fuel at all. High-tech catapults with payloads of titanium, aluminum, magnesium, etc. could be slinging it all back home.

NOT EVERYONE IS THRILLED at the prospect. Among those filled with loathing and dismay are Navajos, Hindus, practicing witches, and legions of secularists for whom the moon represents religion's last dim chime. Eco-activist Rick Steiner of Alaska has petitioned the United Nations to have the moon declared a World Heritage Site on the theory that man, having made a latrine of Earth, will do the same to the moon, only faster.

The nobility of that impulse, I have to say, struck me a few beats late. When I first heard talk of "malling the moon," my thoughts jumped to: Here come people with lots of money about to do things to make lots more money, none of which I will ever get. I want to be upfront about this, how my own forlorn relationship to other people's wealth is part and parcel of my animus against the ultra-rich. I fully believe that much of the misery in this fine pretty world is caused by the privileged class enjoying its obscene privileges. But the rest of my grievance derives from the grinding injustice to me personally. *Where's mine*? So much money in the world and none touches me. It's like the miracle of the Red Sea.

Of course top players in the space business are necessarily loaded. They have daring pantechnicons of ideas, of which we have already seen early fruits. I've no doubt that when it comes to the moon, these innovators will make many dazzling additions to the catalogue of human ingenuity.

Historically, it's true, our ingenuity has been something of a mixed bag. One might even call it the double helix of enterprise and stupidity that dooms us whenever we get near tools. I think in this regard of Thomas Midgley. He was working as a chemist for General Motors in the 1920s when he realized he could eliminate engine knock by adding tetraethyl lead to gasoline. This was great for car sales, but the stuff was tricky to produce. Workers handling the new formula suffered lead poisoning so severe it caused nerve damage and wild hallucinations. At the Deepwater, New Jersey, factory they were beating off clouds of imaginary insects. The problem did get straightened out. Not medically, but politically it was totally taken care of. Lead goes up; life goes on. But Midgley's not done. He turns around and invents Freon, first of the fluorocarbons. So now he's the father of ozone-eating coolants too. Later he contracted polio. In 1944 he was struggling with some rigging he'd invented to pull himself out of bed and got tangled in it and accidentally strangled to death, a symbolic gesture if there ever was one.

What's to be done with such a man? Well, put him on the moon and he'd be no threat at all because the moon has no atmosphere. It's idiot-proof in that regard. This is what makes the moon ideal for

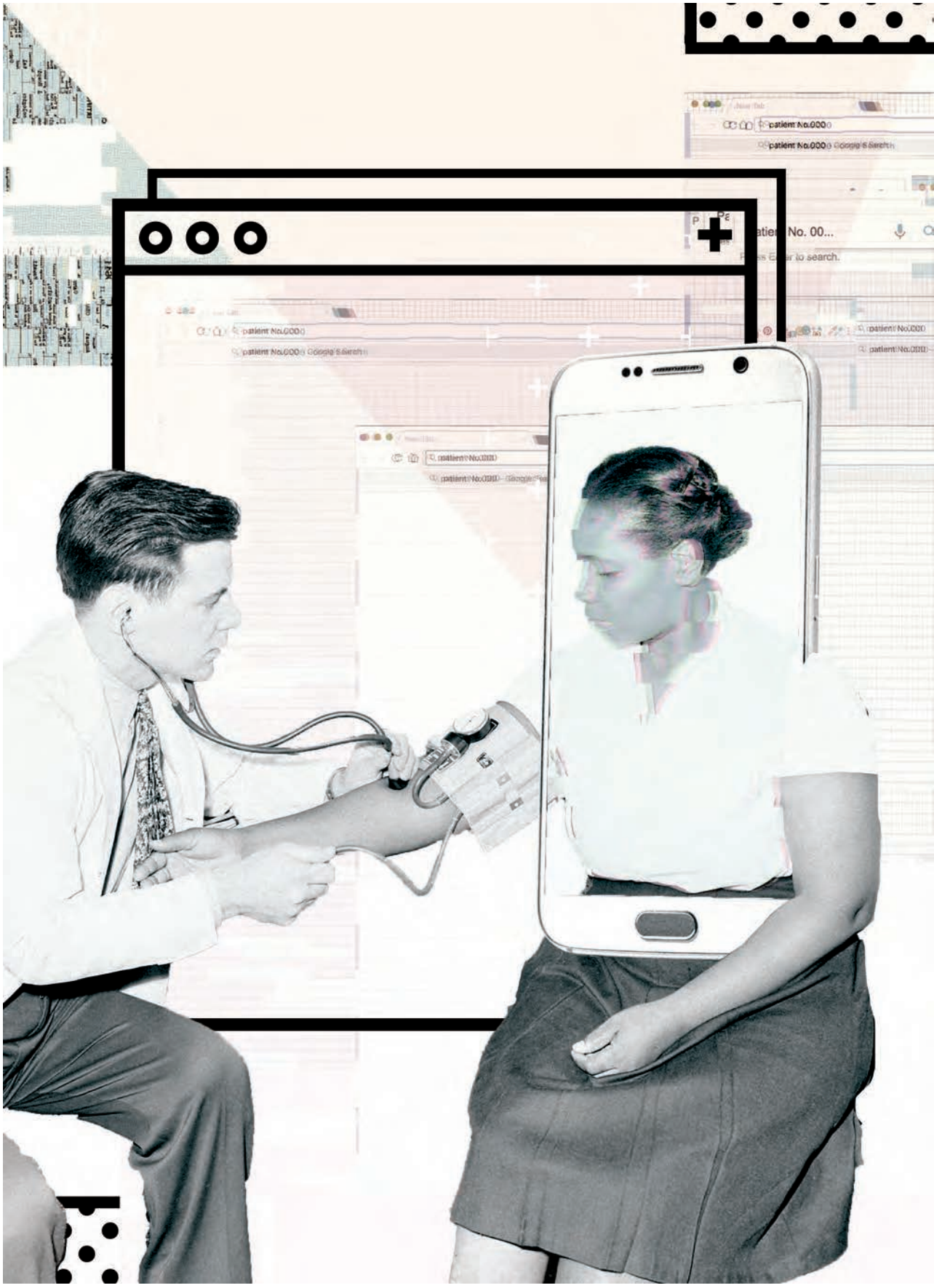
There is a lively competing interest in putting solar panels on the moon.

so many kinds of work. It may be a land of boiling, freezing, radiation, and chalk, but our genius can fly free there without opprobrium and reprisals. And a lucky thing too if we have to shift operations in any big way.

We're so busy, all us little Midgleys, that it may just be a question of what triggers the diaspora. Oil? According to one group of catastrophists we'll be ruined suddenly and soon by "peak oil," the term of art for running out of it. But other things could go, *snap*, like that. Peak water, peak farmland, peak fish: Pick your death blow. Peak bees! *Where the bee sucks there suck I but now I suck alone*. You've heard of course about bees disappearing. Perhaps you thought, as I did, of a fuzzy few creeping around on the roses. Not so. We're talking great slabs of bees vanishing wholesale. In California the owner of a commercial apiary lost 2 billion bees in two weeks. Colony collapse disorder: It's happening all over the world. Pretty soon fruits, vegetables, pfffft. What's causing it? Everybody's got a theory: Varroa mites, genetically modified crops, cell phone radiation, hillbilly breeding techniques … No one's sure. But that's not the weird part. What's weird is their mode of departure. Because they are literally disappearing. It's not as though that guy in California was suddenly shuffling through 40 tons of dead bees, or his neighbor came over and said, "Hey, get your fucking dead bees off my land." There were no corpses found or reported. The bees were just gone. It's as if we've somehow stumbled upon a brand-new recipe, a witches' brew so potent it doesn't just kill things; it makes them actually dematerialize. But since we don't know the formula, all we can do is watch its effects. Where will it strike next? One day we'll step out the door and the dogs or the wheat won't be there. And so it'll go, one thing at a time, until finally people start to vanish and that's when the panic starts. Now crowds are pouring through the streets, trampling others on the run from dirty-bomb threats, London fogs of CO_2, eructations of methane, rogue viruses, not to mention shortages of food, water, Xanax, whatever it is singly or in combination that sends people streaming toward—toward what? Nobody knows—men, women, children, even the elderly who thanks to medical breakthroughs have joined the growing army of the dead who won't lie down …

But to return to first principles: Corporations, hand-in-glove with governments, will hegemonize the moon. Broad-brush, that's the plan. Thereafter, whether Earth somehow escapes immolation and becomes the moon's robust trading partner, or turns into a global hospice with thousands of acres of methane rising from ancient graves and the seas so full of jellyfish they look like cobblestones, the human race endures. I'm not promoting here the rancid mythology that business success drives the public good. Rather, I think the process will probably resemble the tale of the scorpion and the frog. Suffering humanity (frog) hitches a ride on the back of the scorpion, hoping against hope that the scorpion will overmaster its own instincts and save them both—which, given the stakes, it may or may not do.

POPE BROCK is a writer, teacher, and DJ living in Arlington, Massachusetts. He is the author of three books: *Indiana Gothic*; *Charlatan: America's Most Dangerous Huckster, the Man Who Pursued Him and the Age of Flimflam*, and *Another Fine Mess: Life on Tomorrow's Moon*.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Getting Googled by Your Doctor

Will mental health clinicians become liable for missing your latest Facebook post?

BY ERENE STERGIOPOULOS

ONE DAY NOT LONG AGO, police forcibly brought a man to the hospital after he updated his profile picture on Facebook. He was in his late 20s and had a long history of suicide attempts, a diagnosis of bipolar disorder, and a close relationship with his mental-healthcare team, which typically consists of physicians, nurses, and social workers. On the day of the incident, the team leader—the doctor who makes medical treatment decisions—reportedly stumbled on his Facebook page by accident. Since she had visited it several months earlier to keep tabs on him, his name autofilled the search box when she typed the first name of her friend, the same as the client's. It brought up his profile picture, and it was concerning: He was holding what looked like a gun pressed to his head. The team leader thought he'd already gone through with it—other photos showed suicide letters to a friend and his parents.

When he got to the hospital, he let his doctors know how angry he was at their intrusion and his involuntary hospitalization. He denied wanting to end his life, but remained there for several days, during which time police searched his house for weapons, finding only a pellet gun.

The case of this man, who went unnamed to protect his identity, appeared in a 2012 journal article by University of Washington clinical psychologist Keren Lehavot and her colleagues. The incident is extreme, but isn't necessarily an outlier; the Internet has propelled mental health clinicians into new ethical and legal territory. It raises questions about the accuracy of online information, patients' right to privacy, and doctors' liability when it comes to their patients' online behavior. If the doctor-patient relationship was a meticulously crafted house of cards, held together by historically entrenched relations of power and professionalism, then the Internet is the toddler that toppled the house and bent the cards. It's becoming a common, if not an uneasy, practice for mental health clinicians to Google their patients and make decisions based on online information.

PHOTOCOLLAGES BY JESSICA LIN

Practitioners might wonder whether the patient is telling the whole story—might an online search add more perspective?

"Anecdotally, I know we do it all the time," says Liliya Gershengoren, a psychiatrist and professor at Cornell University. She recently concluded from a survey she conducted that an overwhelming majority of psychiatrists and residents at one United States academic hospital had Googled a patient at some point in their careers. "I wanted to get some data to back up my anecdotal data," she says.

In May, she presented these survey results at a panel at the American Psychiatric Association's 2017 annual meeting. Out of 48 staff doctors and 34 residents who responded anonymously, 93 percent of staff and 94 percent of residents reported Googling a patient at least once. She found that 17 percent of staff and 40 percent of residents Googled their patients on a frequent or semi-regular basis in the ER (compared to 5 percent of staff and 15 percent of residents in inpatient settings).

Searching for patients' information online gives physicians a way to gather collateral data about a patient who either cannot or will not communicate important clinical information, says Paul Appelbaum, a psychiatrist, professor at Columbia University, and world expert in medical ethics and the law. He also presented at the panel on patient-targeted Googling, and recently co-authored an article in the *Harvard Review of Psychiatry* on the ethics of using patients' digital footprints in mental healthcare.

Appelbaum wasn't surprised to hear that staff and residents frequently find themselves Googling patients in the ER. That online collateral information is especially useful there, he says, where patients may be psychotic, intoxicated, or suicidal. In these acute settings, social media can provide clinicians with valuable context to make decisions—whether the patient uses drugs

or alcohol, has self-harmed, or has family support is often evident online.

Clinicians may also Google their patients during ongoing treatment, whether in a clinic or private office. Here, practitioners might wonder whether the patient is telling the whole story—might an online search add more perspective? In some cases, patients themselves might request that their healthcare providers check their online profiles, a scenario that 12 percent of physicians encountered in the outpatient setting in Gershengoren's study. Videos, for example, can reveal important information to clinicians about patients' mental status, including their mood, rate of speech, or the extent to which their thoughts are organized. "I've had patients say that they don't want to talk to me because, 'It's already online, so go on and check my YouTube page,' " says John Luo, a psychiatrist and University of California professor of psychiatry and medical informatics, who also presented on the panel.

There are risks inherent in learning about patients from their online footprints: Clinicians don't always know if their patients' online information is accurate or timely, and by accessing it without consent, they risk breaching the patient's privacy and trust. "When treating clinicians know more about their patient than patients think they know, using that information can be extraordinarily awkward," says Appelbaum—you'll eventually need to disclose where you learned it. Luo explains, "When you disclose it, you also have to consider: What does that do to your relationship with that patient, especially if somebody is paranoid?"

IN SEARCHING FOR THEIR PATIENTS ONLINE, clinicians may be unwittingly setting legal precedents for mental healthcare. As more and more providers Google to guide their decisions, they may be shifting the clinical standards to which all practitioners are held. "The standard of care is developed by the clinical community itself," says Appelbaum. "What most people do, or at least what a substantial number of people do, becomes a standard of care."

If practitioners neglect that standard, and something preventable goes wrong, they risk accusations of malpractice. In other words, if patient-targeted online searches become the new standard of care, then clinicians could become liable for information patients post online. If a patient leaves a suicidal message on Facebook, and the clinician misses it, there's a future—seemingly more plausible by the day—in which that clinician could be sued for malpractice if the patient then attempts suicide.

How likely that future is "will depend on us," Appelbaum suggests, "on the clinical professions and how we choose to use the ability that the Internet is giving us."

Records get routinely accessed by third parties, occasionally without the patient's consent.

The social and legal ramifications of patient-targeted Googling also extend to patients themselves. "By going online and putting what we find in the chart—whether that's a summary or a cut-and-paste excerpt or a screenshot—we are creating a new kind of medical record information that didn't exist previously," says Appelbaum. "Unlike some of those sources—which may be hard to find, or ephemeral, and may ultimately disappear—medical records are forever."

Those records get routinely accessed by third parties, occasionally without the patient's consent. The most obvious culprits are insurance companies, which regularly review medical records. But medical charts also play a role in legal proceedings, in cases of accidental injury, child custody disputes, or criminal cases. The data they contain can also be a target of criminal profiteering. "We have hackers looking for that information," Luo explains, "because they can sell it."

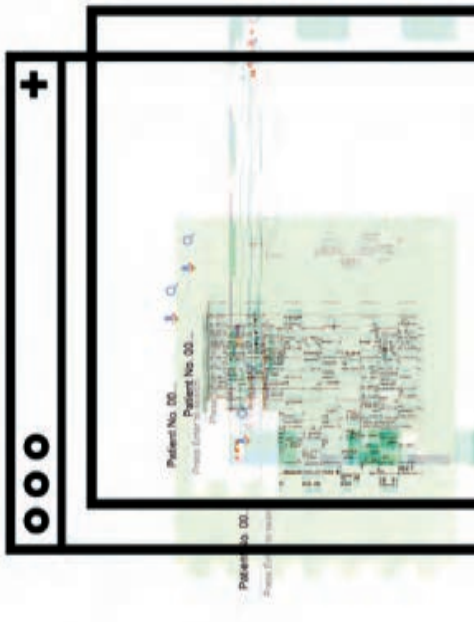
The growing openness of our lives, which we increasingly spend online, has given rise to a new kind of understanding between patients and practitioners—and it goes both ways. "Everything about our online lives is available to all of our patients, just as their information is available to us," says Appelbaum. "So that's an equalizing change in terms of power and knowledge. But it's something that clinicians have to learn to deal with."

WHILE DOCTORS MAY FEEL more exposed than ever, there are certainly benefits to this shift. In cancer care settings, for example, where mental health clinicians can offer psychotherapy to medically ill patients, online platforms provide new spaces for building community. A guideline on using social media, published recently in the *Journal of Oncology Practice*, explains

that, while clinicians should maintain professional boundaries and privacy, there are many positive ways to connect with patients online. Some doctors have created Facebook communities to help patients connect with fellow patients and families, creating a platform to share coping strategies and provide reliable medical information vetted by the clinician.

Gershengoren, who works as a medical psychiatrist, echoes these guidelines. "If we can use social media for any kind of needs of our patients—like emotional needs, or psychosocial issues—I'm very much in favor of that. Especially because I think for a lot of patients, social media is much more familiar to them than anything else."

ERENE STERGIOPOULOS is a writer and medical student in Toronto. Her work has appeared in *Hazlitt*, *Motherboard*, and *Discover*.



Is Tribalism a Natural Malfunction?

What computers teach us about getting along

BY SIMON DEDEO

FROM AN OFFICE AT CARNEGIE MELLON, my colleague John Miller and I had evolved a computer program with a taste for genocide.

This was certainly not our intent. We were not scholars of race, or war. We were interested in the emergence of primitive cooperation. So we built machines that lived in an imaginary society, and made them play a game with each other—one known to engender complex social behavior just as surely as a mushy banana makes fruit flies.

The game is called Prisoner's Dilemma. It takes many guises, but it is at heart a story about two individuals that can choose to cooperate or to cheat. If they both cheat, they both suffer. If they both cooperate, they both prosper. But if one tries to cooperate while the other cheats, the cheater prospers even more.

The game has a generality that appeals to a political philosopher, but a rigorous specificity that makes it possible to guide computer simulations. As a tool for the mathematical study of human behavior, it is the equivalent of Galileo's inclined plane, or Gregor Mendel's pea plants. Do you join the strike, or sneak across the picket line? Rein in production to keep prices high, or undercut the cartel and flood the market? Pull your weight in a study group, or leave the work to others?

Our simulation was simple: In a virtual world, decision-making machines with limited powers of reasoning played the game over and over. We, as the unforgiving account-keepers, rewarded the ones who prospered and punished the ones who did not. Successful machines passed their strategies to the next generation, with the occasional slight variations designed to imitate the blind distortions typical of cultural evolution.

We also gave the machines a simple language to think with and enough resources to have memories and to act on them. Each generation, paired machines faced each other multiple times. This is how life appears to us: We encounter our trading partners over and over, and how we treat them has consequences.

ILLUSTRATION BY FRANCESCO IZZO

Our model for the world was two Robinson Crusoes encountering each other on the sands.

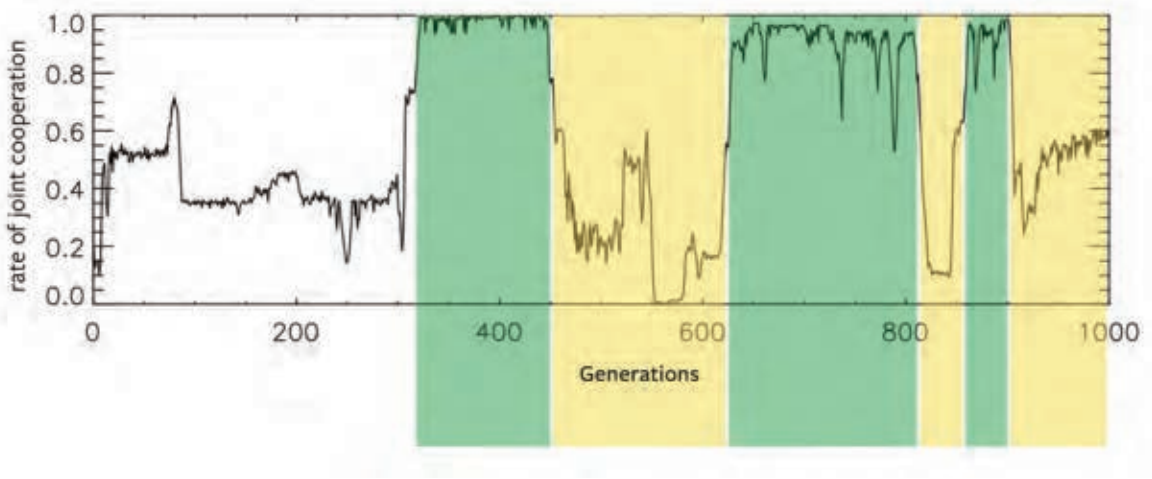
When we ran these little societies forward, we expected to confirm what many believed to the optimal strategy for playing Prisoner's Dilemma: tit-for-tat. A machine playing this strategy begins by keeping its promises, but retaliates against an instance of cheating by cheating, once, in return. Tit-for-tat is the playground rule of honor: Treat others well, unless they give you reason otherwise—and be reasonably quick to forgive.

Yet when we looked at the output of our simulations, where the strategies were free to evolve in arbitrary directions, we saw something very different. After an early, chaotic period, a single machine would rise rapidly to dominance, taking over its imaginary world for hundreds of generations until, just as suddenly, it collapsed, sending the world into a chaos of conflict out of which the next cycle arose. An archaeologist of such a world would have encountered thick layers of prosperity alternating with eras of ash and bone.

Instead of an orderly playground ruled by cautious, prideful cooperators, the population produced bizarre configurations that made no sense to us. That is, until one evening, in the office and after filling up pads of graph paper, we stumbled onto the truth. The dominant machines had taken players' actions to be a code by which they could recognize when they were faced with copies of themselves.

In the opening moves of the game, they would tap out a distinct pattern: cooperate, cheat, cheat, cooperate, cheat, cooperate (for example). If their opponent responded in exactly the same fashion, cheating when they cheated, cooperating when they cooperated, they would eventually switch to a phase of permanent cooperation, rewarding the opponent with the benefits of action to mutual advantage.

Woe, however, to those who did not know the code. Any deviation from the expected sequence was rewarded with total and permanent war. Such a response might take both machines down, in a kind of a digital suicide attack. Because the sequence was so hard to hit upon by accident, only the descendants of ruling machines could profit from the post-code era of selfless cooperation. All others were killed off, including those using the tit-for-tat strategy. This domination would last until enough errors accumulated in the code handed down between generations for dominant machines to stop recognizing each other. Then, they would turn against each other as viciously as they once turned against outsiders, in a kind of population-level autoimmune disease.



SHIBBOLETH MACHINES

Simulations of our machines show initial levels of apparently random behavior giving way, around generation 300, to high rates of cooperation that coincide with near-complete domination by a single machine that drives others to extinction. This enforced cooperation collapses around generation 450. From then on, the system alternates between these two extremes. Green and yellow bands correspond to eras of high and low cooperation, respectively.

Woe to those who did not know the code

As long as the codes lasted we called them Shibboleths, after the tribal genocide recounted in the Old Testament Book of Judges:

> And the Gileadites took the passages of Jordan before the Ephraimites: and it was *so*, that when those Ephraimites which were escaped said, Let me go over; that the men of Gilead said unto him, *Art* thou an Ephraimite? If he said, Nay; / Then said they unto him, Say now Shibboleth: and he said Sibboleth: for he could not frame to pronounce *it* right. Then they took him, and slew him at the passages of Jordan: and there fell at that time of the Ephraimites forty and two thousand.

Shibboleths are a common feature of human culture and conflict. Finns who could not pronounce *yksi* (meaning "one") were identified as Russians during the Finnish Civil War. Tourists in downtown Manhattan quickly out themselves if they pronounce Houston Street like the city in Texas.

Here our machines had used them to dominate a population so effectively that no others could survive. Even after the era was over, it was their descendants that inherited the ashes. The blind hand of evolution had found a simple, if vicious, solution.

It was a stark and brutal social landscape. But we had given our machines very limited resources to think with. How would two perfectly rational machines act in a conflict, if they each knew the other was similarly perfectly rational? By the very nature of rationality, two completely rational beings, confronted with the same problem, ought to behave in the same fashion. Knowing this, each would choose to cooperate—but not out of altruism. Each would recognize that if it were to cheat, its opponent would too, making them both losers in the game.

The two endpoints establish a spectrum. At one end are our minimally-calculating machines, parochial zero-points of culture that naturally, we found, distilled down to a vicious tribalism. At the other end is the inevitable cooperation of the perfectly rational agent.

On this line between beastly machines and angelic rationality, where do we find the human species?

IF WE HUMANS ARE SUPER-RATIONAL, or at least on our way there, there is reason to be optimistic. Francis Fukuyama might have been thinking along these lines when he penned his end-of-history thesis in 1992. Though Fukuyama's argument was rooted in 19th-century German philosophers such as Friedrich Nietzsche and Georg Wilhelm Friedrich Hegel, we might rewrite it this way: A sufficiently complex simulation of human life would terminate in a rational, liberal-democratic, and capitalist order standing against a scattered and dispersing set of enemies.

Fukuyama's argument was based not just on philosophical speculation, but on a reading of then-current events: the collapse of communism, the flourishing of electronic media, the apparently frictionless opening of borders, and a stock market beginning an epic bull run.

Today his thesis seems like a monument to the dreams of an earlier era (one chapter was titled "The Victory of the VCR"). Our cultures are evolving today, but not, it seems, toward any harmony. The chaos of the 21st century makes our simulations feel immediately familiar. Two decades after 9/11, even the Western liberal democracies are willing to consider dark models of human behavior, and darker theorists than Fukuyama.

Carl Schmitt, for example, who saw the deliberative

A NEW YORK CITY SHIBBOLETH Local New Yorkers can quickly identify a tourist through his or her mispronunciation of this downtown street name.

LILLISPHOTOGRAPHY / ISTOCK

elements of democracy as window dressing on more authoritarian forms of power. Or Robert Michels, whose studies of political inequality led him to see democracy as a temporary stage in the evolution of society to rule by a small, closed elite. As intellectuals at both political extremes increasingly see the possibility of a rational political order as a fantasy, Shibboleths take up their role in defining racial, national, and religious boundaries and appear once again to be ineradicable features of political life.

There is a great, and rich, valley between these philosophies, and another between the computer models that match them—between the simple, violent and less-than-rational agents that John Miller and I simulated, and the super-rational cooperators that Fukuyama might have considered to be waiting at the end of history. The models, at least, encourage a guarded optimism.

Researchers associated with meetings at the Machine Intelligence Research Institute (MIRI) in Berkeley have studied the behavior of rational but resource-limited machines who could inspect each other's source code. Such transparency might seem to solve the problem of cooperation: If I can predict what my opponent will do by simulating his source code, I might decide cheating is not worth the cost. But what if my opponent's code includes a simulation of what I will do as a consequence of running that simulation, and tries to exploit that knowledge? Without the symmetry of perfect rationality, this problem leads to some

extreme mental contortions.

Some of the machines in MIRI's bestiary might remind you of people you know. "CliqueBot," for example, simply cooperates with anyone who shares the same source code. It only cares about codes that match its own letter-for-letter. "FairBot," on the other hand, tries to look beneath surface differences to prove that an opponent will cooperate with someone like itself. Informally, FairBot says, "if I can prove that my opponent will cooperate with me, I'll cooperate with him."

How do these machines get along? While the full solution is a paradox of regress, studies of predictive machine behavior in a Prisoner's Dilemma standoff provide the comforting answer that mutual cooperation remains at least possible, even for the resource-limited player. FairBot, for example, can recognize similarly-fair machines even if they have different source code, suggesting that diversity and cooperation are not impossible, at least when intelligence is sufficiently high.[1]

Even the genocidal machines at the violent end of the spectrum may carry a heartening lesson. They emerged from the depths of a circuit board, simulated on a supercomputer in Texas. They had no biological excuse to fall back on. Maybe we, too, shouldn't make excuses: If a behavior is so common as to emerge in the simplest simulations, perhaps we ought neither to fear it, nor to idolize it, but to treat it, the same way we do cancer, or the flu.

What if we saw tribalism as a natural malfunction of any cognitive system, silicon or carbon? As neither a universal truth or unavoidable sin, but something to be overcome?

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53

DO MONSTERS HAVE an expiry date? They're not just dangerous, after all, or evil, or frightening. They challenge our categories. They are perversions of the natural order.

Which means they have a special relationship with science. Once we study the monster—some disease, say, or geocentrism, or the unfamiliar "other"—we expand our ontology to create a space for it. The idea may still be difficult or unpleasant, but it ceases to be monstrous.

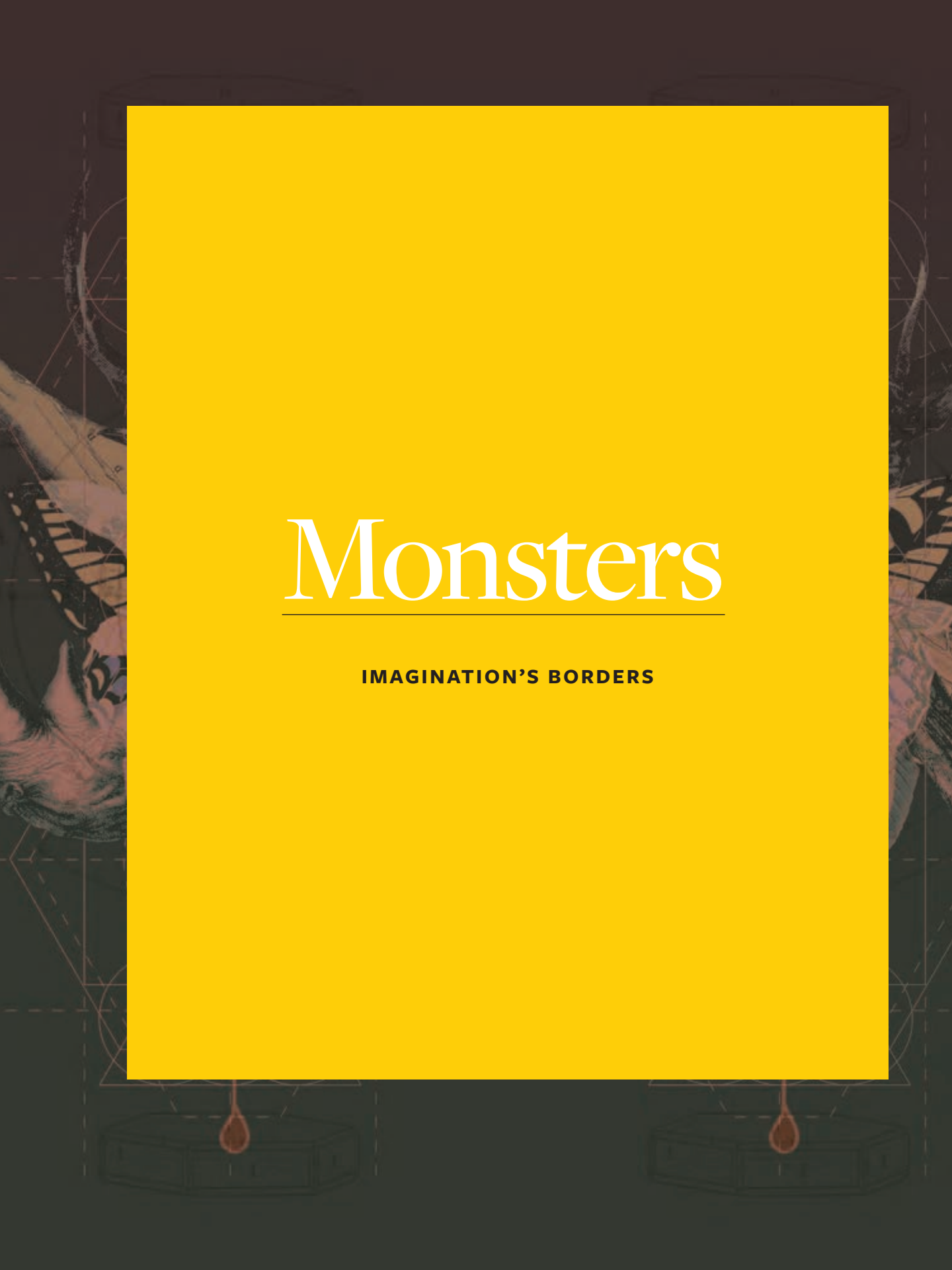
That makes science the slayer of monsters. Today, four-odd centuries after the beginning of Enlightenment science, do we have any monsters left? And if we don't, is that a problem?

Welcome to "Monsters."

—MS

"The clustering of cases suggested the new disease was infectious, and the summertime peak of cases suggested it was spread by something in the water."

KATHARINE WALTER
"What We Get Wrong About Lyme Disease" p.66



Monsters

IMAGINATION'S BORDERS

What We Get Wrong About Lyme Disease

The stories we tell about the epidemic get things backward

BY KATHARINE WALTER

MY SISTER CAMILLA AND I stepped off the passenger ferry onto the dock at Vineyard Haven, Martha's Vineyard's main port, with a group that had already begun their party. They giggled, dragging coolers and beach chairs behind them. We competed to see how many items of Nantucket red we could spot.

Not that we were wearing any. Camilla wore shorts with white long underwear underneath, and I wore beige quick-dry hiking pants. Both of us had on sneakers with long white socks. It was late June, perfect beach weather. The water sparkled. But we weren't headed toward the ocean. We were there to hunt for ticks.

On the island, we hopped in a cab. Camilla looked longingly out the window as we passed the turns for the town beach and Owens Park Beach. The driver pointed out the location of the famous shark attack beach from *Jaws*. We drove on south to Manuel Correllus State Forest, an unremarkable park in the center of the island and the farthest point from any beach.

Deer ticks, or blacklegged ticks, are poppy-seed sized carriers of Lyme disease. We needed to collect 300 before the last ferry returned to Woods Hole, Massachusetts that night. We each unfurled a drag cloth—a one-meter square section of once-white corduroy attached to a rope—and began to walk, dragging the cloth slowly behind us as if we were taking it for a stroll. The corduroy patch would rise and fall over the leaves and logs in the landscape, moving like a mouse or a chipmunk scurrying through the leaf litter. Ticks, looking for blood, would attach to the cloth. Every 20 meters, we'd stoop to harvest them.

Tick collecting made it to *Popular Science*'s 2004 list of worst science jobs alongside landfill monitor and anal wart researcher. On cool days, though, sweeping the forest floor, kneeling to pluck ticks from corduroy ridges, the job became rhythmic. I felt strangely close to the forest. As I soon found out, the work got me closer to people, too.

Sometimes hikers would stop by, curious, then

CJP / GETTY IMAGES; JOHN FLANNERY / FLICKR

PHOTO COLLAGE BY FRANCESCO IZZO

THE GLAMOUR OF IT ALL
Camilla Walter harvesting deer ticks on Prudence Island, in Rhode Island's Narraganset Bay. Tick collecting made *Popular Science*'s 2004 list of worst science jobs.

repulsed. They would want confirm the proper way to pull off ticks (with tweezers planted close to skin, perpendicularly), or to tell us about their diagnoses. Lyme disease isn't like many of the diseases studied by my friends in the epidemiology department, where I was a doctoral student. No one talks about their grandmother's syphilis infection, caused by *Treponema pallidum*, another spirochete bacterium.

But once people heard what Camilla and I were collecting, stories of brushes with ticks and family members' diagnoses were shared freely. I quickly became the "tick girl." When I started my dissertation I was preoccupied by the ecological question: How have humans altered the environment and triggered a disease emergence? By the time I finished, I realized that far more interesting were the rich and revealing tick stories shared with us along the way.

ILLNESS MAKES US TALK. "This is true of all forms of pain and suffering," Arthur Kleinman, an anthropologist and physician at Harvard University, told me. We talk about illness "to seek assistance, care, and in part to convey feelings about fear, anxiety, or sadness." In his book, *The Illness Narratives*, Kleinman writes that "patients order their experience of illness ... as personal narratives." These narratives become a part of the experience of being sick. "The personal narrative does not merely reflect illness experience, but rather it contributes to [it]."

The result is a peculiar togetherness. Once, a friend's mom emailed that she'd just pulled off her first tick of the season, from her pubic hair: "I'm guessing it doesn't it surprise you to hear, Katie, that you came to mind almost immediately when I discovered the little bugger? I'm afraid that ticks and you will be forever

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The wilderness that we've feared, romanticized, and valorized is a fantasy.

linked in my mind." Naturally some took the motif too far. One creepy grad student thought that, because I was standing in front of a tick poster at an academic conference, I'd want to hear about the time he pulled a tick off his dick.

The country singer Brad Paisley romances the tick: "I'd like to see you out in the moonlight / I'd like to kiss you way back in the sticks / I'd like to walk you through a field of wildflowers / And I'd like to check you for ticks." I'm with Paisley here. Creeps aside, tick grooming is an act of love. My sister and I were diligent in the tick checks we gave ourselves and each other. Most nights, we'd pull off several at the campsite showers.

Tick stories mostly fell into a few categories. There were the boastful ones. On Washburn Island, a tiny island a few hundred yards off of Cape Cod, two hairy, fully-bearded park rangers, Steve and Steve, couldn't be bothered to pull off their ticks. For most of the summer, they lived outside in tents and tarps and always had a few handfuls of ticks embedded in their skin. The Steves boasted that they'd each been infected with Lyme disease and babesiosis, a parasitic illness also carried by deer ticks, on and off for the last several years. Theirs was a backcountry machismo, as if their burliness made them immune to the intrusion of the forest twigs and ticks upon their bodies. Their symptoms, though, were presumably as real as anyone else's.

The bulk of people's reactions to the disease reflected a confused anxiety about boundaries. En route to a wedding in Easton, Connecticut, deep in Lyme country, someone found out that I was a tick girl and asked if they should be worried. The wedding was on a farm, an edge habitat where weedy species—mice, chipmunks, and robins—proliferate. Weedy animals include some of the best hosts for the Lyme disease bacterium. They can be infected with a tick bite and pass on the bacterium to the next tick that feeds on them, continuing unbroken chains of transmission. Deer, which are also hosts for ticks, thrive in these fragmented habitats, too.

I recited my usual tick check endorsement: Shower and check yourselves at the end of the night and you'll be fine. The Lyme bacterium is only transmitted after the tick has been attached for two or three days. Still, when guests filled the lawn for corn hole and cocktails, I couldn't help but notice all the cocktail dresses and open heels, ankle-deep in grass. The next morning,

one woman told me she'd plucked three ticks from her ankle.

Worry bled to fear. On Cuttyhunk Island, the most remote of the Elizabeth Islands, a necklace of islands spilling off of southern Cape Cod, my sister and I were generously hosted by a woman I'll call Susan, a self-trained student of the Lyme epidemic. "Ticks have become the bane of island existence," Susan gravely told me shortly after I arrived. By 2010, everyone Susan knew on the island was taking doxycycline, the antibiotic most commonly prescribed for Lyme disease. She and her husband arrive in Cuttyhunk at the start of the summer season armed with bottles of it and take it prophylactically. Every time they pull off a tick, they take three doses, spread over 24 hours. This is not recommended by the CDC (the Centers for Disease Control and Prevention). Doxycycline makes your skin sensitive to the sun, so their regimen makes it necessary to wear a hat and lots of sunscreen or stay inside.

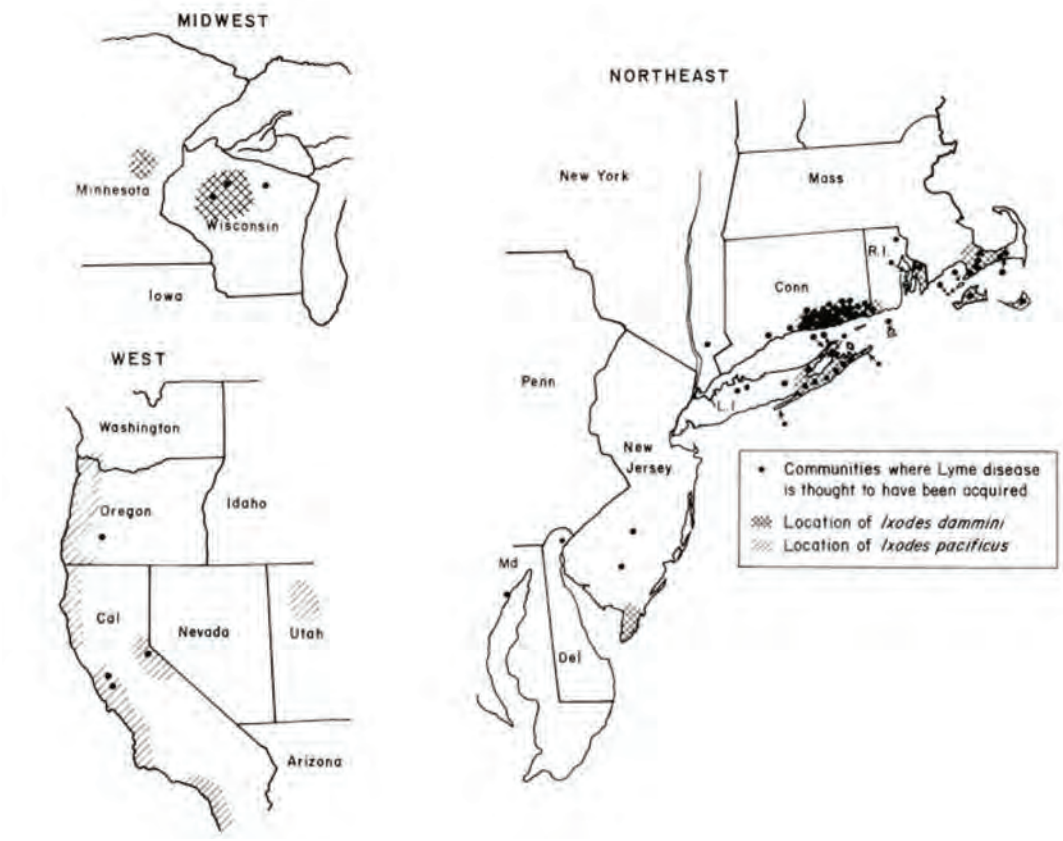
Susan fenced in her lawn to keep out rabbits, which can host adult ticks, then raised the fence to defend against deer. "Our house is ringed with Damminix tubes, the yard fenced, grass mowed short, and still they turn up in the bed with us," she told me. (Damminix tubes hold cotton infused with an insecticide that kills ticks.) We slept in her son's room, crisp and nautically themed and lined with file cabinets full of scientific articles about Lyme disease epidemiology and ecology, local and national reporting on the epidemic, and printed email exchanges with epidemiologists and local politicians. Susan is now spearheading the island's Tick Eradication Campaign. Her plan for eradication was ambitious, she admitted. But, she asks: "Wouldn't it be nice to be able to say that you are stepping onto a tick-free island where a sunburn is the most dangerous health risk?"

THE IDEA THAT the natural and human exist in separate realms is the very "trouble with wilderness," the environmental historian William Cronon wrote in his 1995 book *Uncommon Ground*. The wilderness that we've feared, romanticized, and valorized over the last few hundred years, he says, is a fantasy:

> [Wilderness] is quite profoundly a human creation—indeed, the creation of very particular human cultures at very particular moments in human history ... Wilderness hides its unnaturalness behind a mask that is all the more beguiling because it seems so natural. As we gaze into the mirror it holds up for us, we too easily imagine that what we behold is Nature when in fact we see the reflection of our own unexamined longings and desires.

In the stories told by our doctors, our parks, and the CDC, ticks are invaders. To defend ourselves, we use insect repellent, clothing, and prophylactic antibiotics; fences, signs, and pesticides. "When it comes to pesticides, the environmental toxin par excellence, Lyme patients are often its greatest proponents," writes Abigail Dumes, an anthropologist at Michigan State University. We prefer the risk posed by pesticides to the fear of Lyme, Dumes explained to me. They let us become actors instead of victims. By dosing ourselves with pesticides (or antibiotics), we gain control of our risks. Ticks, on the other hand are uncontrollable. "It's difficult to live with the idea that there are enormous threats and many can't be

By dosing ourselves, we gain control.



LYME EMERGES Allen Steere and Stephen Malawista published these maps of Lyme disease in 1979, just two years after it had been named. They noted a correspondence between disease clusters and areas where two species of black-legged ticks were known to exist.

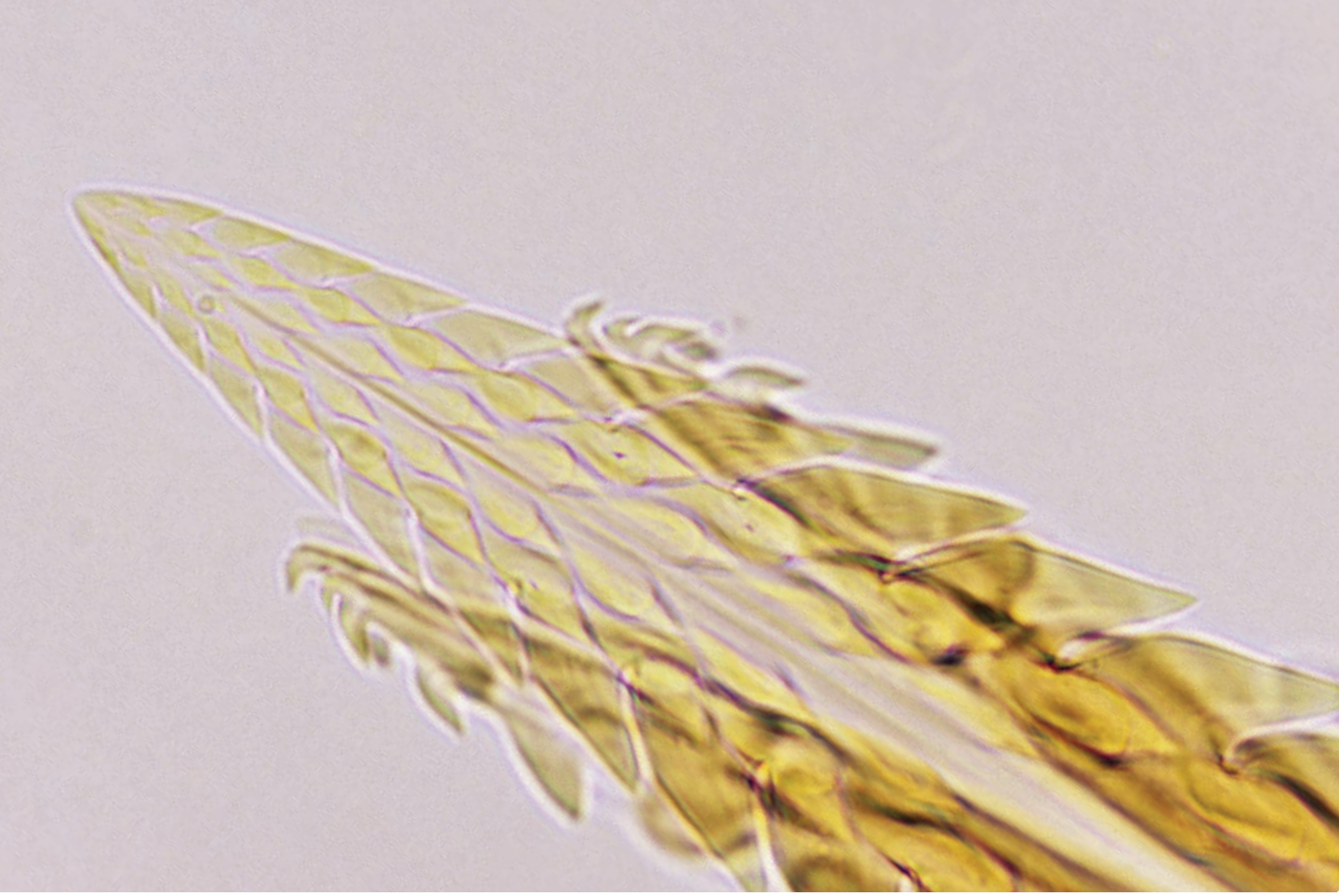
COURTESY OF THE AUTHOR

controlled," Kleinman tells me.

The problem is our defensive barriers aren't working particularly well. Deer ticks are now established across 45 percent of United States counties. Their range has more than doubled in the last 20 years. Reported cases of Lyme disease have more than tripled since 1995 and the CDC estimates that more than 300,000 Americans fall ill each year. The story of tick-as-invader isn't particularly helpful—or complete.

In November 1975, Polly Murray, an artist living in Lyme, Connecticut, contacted the Connecticut State Department of Public Health. Two of her children were sick with what doctors called juvenile rheumatoid arthritis, a disease of joint pain. Their knees were so swollen that they were forced to walk with crutches. Several other neighborhood children had similar symptoms. Arthritis is rare in children. And it is not normally found in clusters. So Murray kept careful notes of her children's symptoms and compiled a list of other sick children.

At first, doctors were dismissive. But Allen Steere, a young rheumatologist at Yale-New Haven Medical Center, was curious. He began to investigate cases in Lyme, Old Lyme, and East Haddam, quiet, wooded communities just east of the mouth of the Connecticut River. Through a surveillance "grapevine," he found 51



PIERCING The hypostome of a deer tick is a piercing organ with recurved teeth.

ED RESCHKE / GETTY IMAGES

residents—39 children and 12 adults—in a community of 12,000 suffering from unexplained arthritis. A quarter of patients also had erythema migrans, an expanding circular rash with a pale center, also called a bullseye. In some neighborhoods, 10 percent of children suffered from this unexplained arthritis. In 1977, in the journal *Arthritis and Rheumatism*, Steere and his team named the set of symptoms Lyme arthritis. They called it "a previously unrecognized clinical entity."

At that point, what caused the symptoms remained a mystery. The clustering of cases suggested the new disease was infectious, and the summertime peak of cases suggested it was spread by something in the water—picked up by swimmers—or by insects. Steere's team tested his patients' blood for dozens of viruses and bacteria. Nothing fit. In 1979, Steere and a colleague mapped out the first 512 cases of Lyme arthritis. The distribution of cases overlapped neatly with what was then the range of deer ticks. Many of Steere's patients lived in wooded areas and had mentioned insect bites. But hundreds of ticks were tested and no pathogen was found.

A few years later, William Burgdorfer, an entomologist at the Rocky Mountain National Laboratories, identified a new spirochete—a corkscrew shaped bacterium, capable of spiraling through the tissues of its hosts—in ticks collected from Shelter Island, a tiny island nestled between the two pointer fingers of Long Island. Sixty percent of ticks collected on the island carried the bacterium. Soon after, spirochetes were found in the blood of people suffering from Lyme arthritis. The Lyme disease bacterium, *Borrelia burgdorferi*, was named in his honor. It cycles silently in forests between ticks and a group of hosts, mostly small

If anyone is an invader here, it's us.

rodents and birds. From the perspective of the bacterium, humans are dead-end hosts and play no role in the spread of disease to new areas.

The modern history of the disease is relatively short: Just 40 years have passed since it was named. This can contribute to the sense that it is a new invader into our pristine neighborhoods and parks. But where did the bacterium come from? Was it truly new? And why did it first appear in a bucolic Connecticut suburb?

SPREADING TICKS AND MIGRATING BACTERIA leave no trace on the environment. Unlike pathogens that spread strictly from human to human (like measles), we cannot trace the history of the Lyme disease bacterium from the history of human epidemics. So, in 1990, biologists turned from medical records to museums. They sifted through old ticks in entomology collections at Harvard University and the Rocky Mountain National Laboratories, testing for bacteria. They found ticks infected with *B. burgdorferi* collected in the 1940s in Montauk Point and Hither Hills, parks near the Hamptons on the eastern tip of Long Island. Museum collections held no ticks before the 1940s.

That effectively doubled the known history of the disease. Then, researchers turned to the hosts themselves. They snipped ear punches from mouse specimens at the Smithsonian Museum, the Natural History Museum in New York, and the Harvard Museum of Comparative Zoology. Mice from Cape Cod in the 1890s turned out to be infected. Now the disease had a century-long history. Scientists studying Ötzi, the Tyrolean Iceman, stumbled upon in 1991 by hikers in the Italian Alps, have found that he was lactose intolerant, had intestinal parasites, severe atherosclerosis—and probably had Lyme disease. This meant the bacterium likely existed in western Europe 5,000 years ago.

To extend the history of the bacterium further back still, my advisors, Maria Diuk-Wasser and Gisella Caccone, and I turned to the 1 million letters of the bacterium's genome. Pathogens evolve as they spread, and their genome carries a historical record of this development. By comparing pathogen genomes collected from different areas, we can build an evolutionary tree and a history of the pathogen's spread. We can also tell how big the population of pathogens is now, and whether it is growing. This is the crux of phylogeography: Use evolutionary relatedness to answer questions about biogeography, the historic and spatial

distribution of genetic diversity. A classic finding in the field, for example, is that the HIV epidemic originated in the French or Belgian Congo around the 1920s.

I began to chase bacteria from as wide an area and from as far back in time as possible. Biologists mailed me ticks in tiny tubes of ethanol from Michigan, Wisconsin, and Virginia. A Styrofoam container filled with dry ice and DNA samples of infected ticks collected across Canada was Fed-Exed to me. Old ticks were harder to come by. At the Yale Peabody Museum of Natural History, I pulled out drawer after drawer of taxidermied *Peromyscus leucopus*, white-footed mice, elegantly arranged in rows, with handwritten labels tied around their right ankles. Many were collected in the 1800s, when natural history museums were filled with hunting trophies. But the taxidermist had been tidy. The mouse skins had been cleaned of ticks. The oldest ticks I could find that were infected and had well-preserved DNA were from the early 1980s. Camilla and I added them to the 7,000 ticks from our summer harvest.

Finally, with 150 complete genomes in hand, my colleagues and I were able to extend the North American history of Lyme disease from a hundred years to many thousands. We drew a new evolutionary tree which showed that the bacterium likely originated in the northeast of the U.S., spreading south and west across North America to California. Birds likely transported it long distances to new regions, where small mammals continued its spread. Imprinted on the bacterial genomes was also a signature of dramatic population growth. As it evolved, it seemed to have proliferated.

Most interestingly, the tree was far older than we'd expected—at least 60,000 years old. Lyme was likely here in North America much longer than that, long before it was first named in the 1970s, long before humans first arrived in North America from across the Bering Strait (about 24,000 years ago), and long before the last glacial maximum, when much of North America was covered by an ice sheet (also about 24,000 years ago). If anyone is an invader here, it's us. Our analysis also showed that the modern epidemic was not sparked by some new mutation that made the bacterium more readily transmissible. It was sparked by changes in ecology, most of which were man-made.

WHEN COLONISTS FIRST ARRIVED in New England, much of the area was forested. White-tailed deer were abundant. Deer ticks, whose distribution is closely tied to that of deer, most likely existed throughout much of the continent, too. Colonists pressed and pleated the complex fabric of New England's forests, grasslands, and swamps into a starched blanket of fenced farmlands. Hunting and deforestation decimated deer populations. By the mid 18th-century, deer had almost entirely vanished. They never disappeared, though. Deer—and likely, deer ticks and *B. burgdorferi*—persisted in refugia, isolated pockets of southern Cape Cod and the far eastern tip of Long Island. Some deer populations were carefully cultivated. In 1698, hunters stocked the Naushon Island, one of the Elizabeth Islands (a few islands north of Susan's Cuttyhunk) with deer. The island soon became a glamourous hunting destination and was purchased by the Forbes family in 1856, whose annual hunting party was attended by Ralph Waldo Emerson and Herman Melville, among others. The earliest record of a deer tick in the northern U.S. was on Naushon Island in 1926.

Beginning in the mid 1800s, farming gradually shifted westward and New England slowly reforested. But only shreds and slivers of forest were allowed to regrow. Deer populations rebounded and the animal spread across a transformed, suburban New England, one in which wolf predators had been exterminated, and where deer hunting was strictly limited. Ticks followed the deer, and *B. burgdorferi* followed the ticks. The sprawling grassy suburban lawn adjacent to a forest patch is the ideal Lyme disease habitat. The majority of tick-borne infections occur here because excellent hosts for *B. burgdorferi* also thrive in these manufactured edge habitats. More recently, climate change has been warming our winters, accelerating ticks' life cycles and extending their range eight miles farther north each year.

The genetic and ecological history of the Lyme disease bacterium make it clear: Neither ticks nor the bacterium are invaders onto our pristine landscapes. They are the beneficiaries of an artificial and fragmented ecology created by the real invaders, us. Having sectioned and sliced the continent into a patchwork, we are confronted with the consequences. "Many of the individuals I spoke with during the course of my

fieldwork moved to or remained in forested suburbs to be 'close to nature,' " writes Dumes. "But 'after Lyme,' many described an experience of becoming 'prisoners of their own paradise.' "

We've built structured domestic spaces on the periphery of the natural world to help us keep alive our fantasy of a wilderness that is pristine but kept at a safe distance. Ticks put the lie to that fantasy. They make us pay attention. They force us to notice and explore the freckles and spots of dirt on our ankles and our partners' ankles. They force us to observe the spaces around us. They are rude reminders that there is no such thing as wilderness untouched by humans or humans detached from nature.

That's a better story than tick-as-invader. This history doesn't offer a tidy answer for how to stem the epidemic. But it shows us that our modern response to Lyme disease—to build more boundaries—echoes the impulse that created the epidemic in the first place. It's not a just problem with Lyme. I defended my doctoral work earlier this year and am now studying another artificial boundary—the one between prisons and the free world—that is creating another epidemic: tuberculosis. My study sites have moved from Martha's Vineyard to Brazilian prisons, but in a few ways, the new disease stories I'm encountering are alarmingly familiar.

KATHARINE WALTER is a postdoctoral fellow at Stanford University.

SYSTEM WIRING

These starburst bunches are chromatophores on the adult squid's skin, stained with antibodies. The radial projections are muscles, and the other connecting lines are likely nerves. The whole picture is only about a millimeter and a half across, but contains so much information that neurobiologist Steve Senft can zoom into the skein of the potential nerve fibers and almost resolve the individual axons. "We can't quite trace out each one, but that 's the goal," says Senft. "It's not so obvious from this picture but [after looking through] hundreds of them, you get an increasingly clear picture of how the system's wired up."

I Am Not a Monster

Science has turned the squid from a storied monster into a marvel

BY REGAN PENALUNA

CEPHALOPODS LOOM LARGE in our cultural mythos. Their long, sucking arms, large, unblinking eyes, and the sheer size of species like the giant squid have creeped us out since at least the Middle Ages, when tales warned merchants of the monsters awaiting them in dark seas, ready to munch on entire crews and ships.

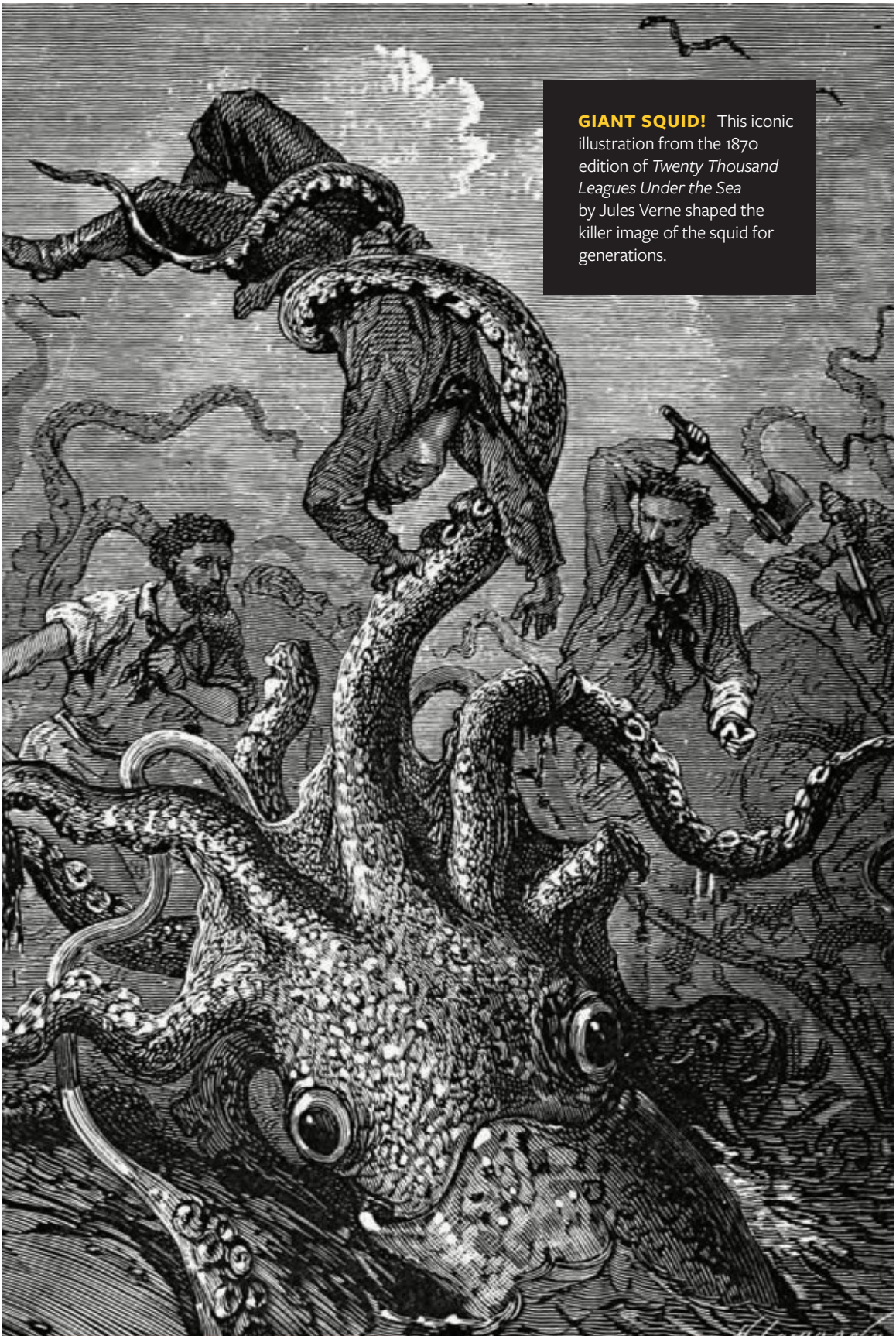
But science has gone a long way to dispelling these terrifying accounts, while at the same time fueling wonder at how spectacularly different cephalopods are from us. We now know they are intelligent creatures whose brains are organized in ways vastly different from our own. Some species of octopuses temporarily recode their genes for adaptive purposes. And squids change the color and patterns of their skin to either hide from predators or communicate with each other. "We might like to make our appearance different with tattoos or cosmetics, but we don't have anything as sophisticated as squids," says Steve Senft, a neurobiologist at the Marine Biological Laboratory in Woods Hole.

Senft studies *Doryteuthis pealeii*, a species of squid about 12 inches long and found in the western reaches of the

Atlantic, from Newfoundland to Venezuela. Embedded in their skin, Senft explains, are tiny, unique cells called chromatophores and iridophores. "The organs are incredibly detailed and foreign from our perspective," he says. "The chromatophores are specially constructed to absorb light of various wavelengths, and the iridophores are constructed to reflect light. The chromatophores are driven directly from the brain of the animal, so that brings the nervous system into play. A squid can express many different patterns. They can flash their fins, arms, heads, and parts of their body called the mantle. They can flash one side of the mantle versus the other, and some of the animals can send waves of reflection down their bodies, which are mesmerizing."

Senft says squids can express dozens of patterns. And what might they be saying to one another? "I don't personally know the language," Senft says. "But it's clear they use a communication system. When squids swim in schools, they show different patterns to different squids. You often see the male squid wear the split-body pattern. He's showing one pattern to a female next to him, and another pattern to a male on the other side of him. Everybody can draw their own deduction, but I think that's just the most obvious example of a set of behaviors that are subtly orchestrated within the schooling of a group of animals."

While Senft works away at the microscope, he encounters images beautiful in their own right. "Sometimes the beauty overwhelms the information," he says. Senft shared some of his squid images with *Nautilus*. They represent a transformation of the squid from monster to marvel. "I think the more people are patient and look at nature around them, the more sense of wonder they have," Senft says.

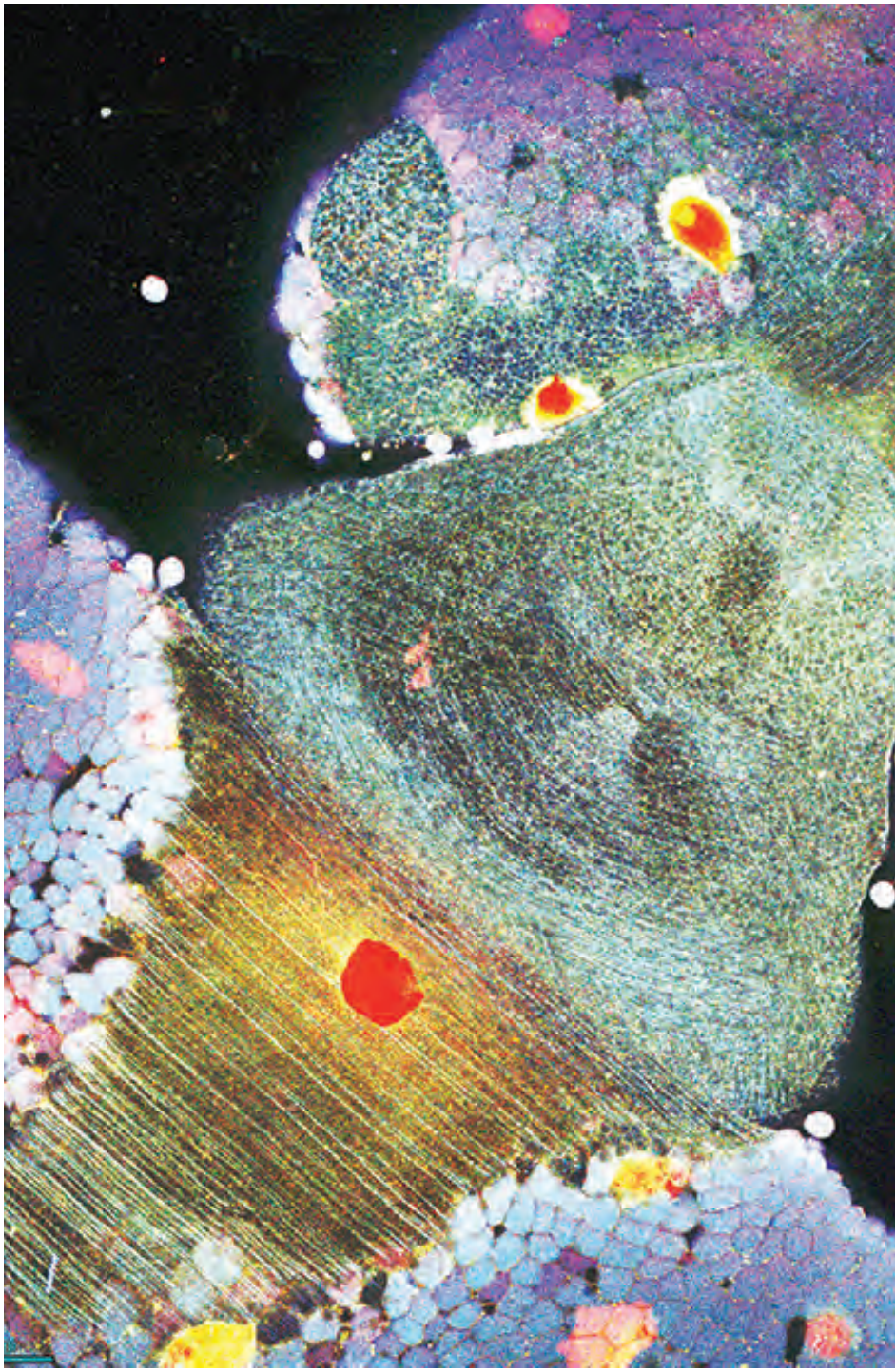


GIANT SQUID! This iconic illustration from the 1870 edition of *Twenty Thousand Leagues Under the Sea* by Jules Verne shaped the killer image of the squid for generations.

WIKIPEDIA COMMONS

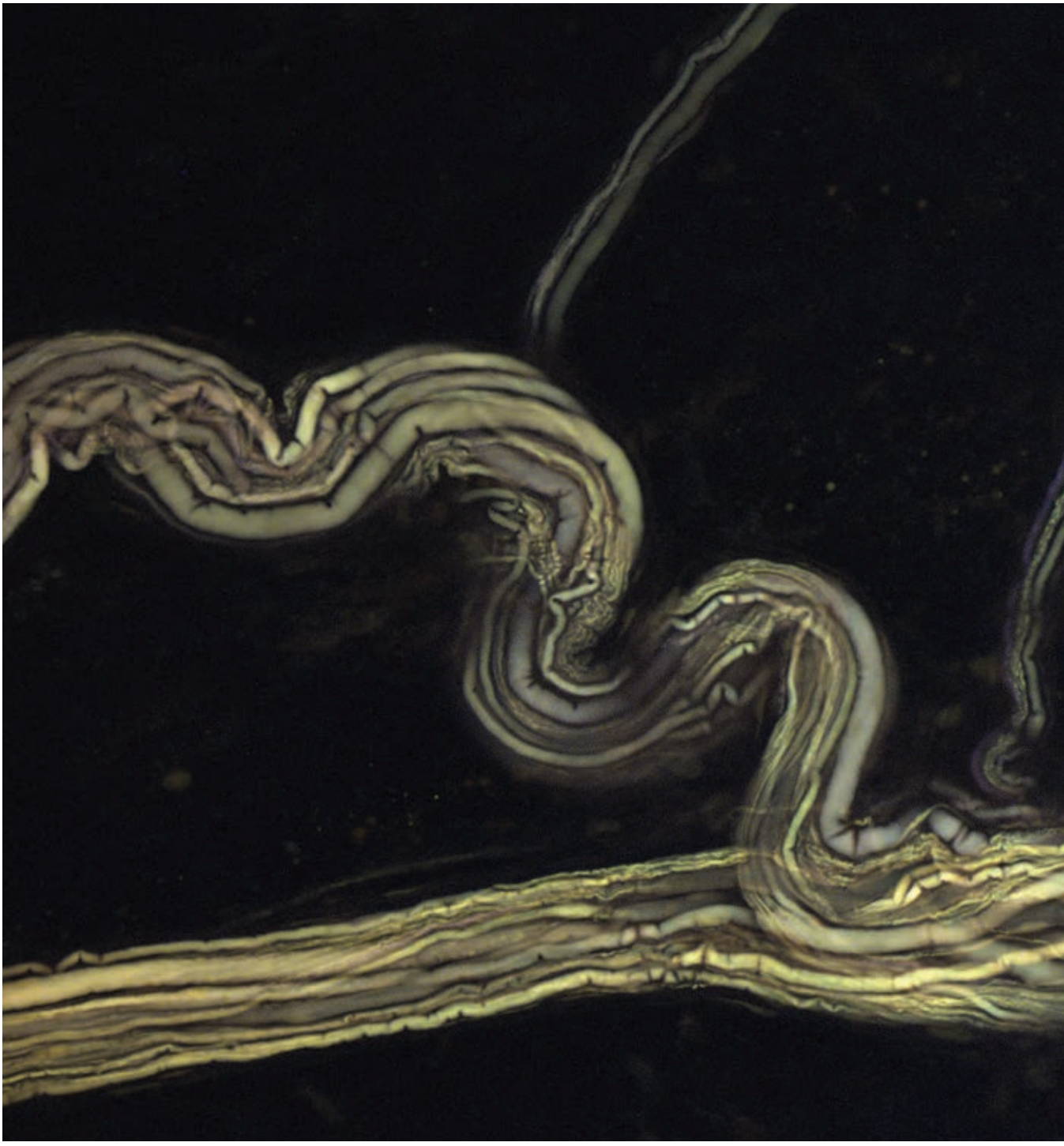
PATTERN MAKERS

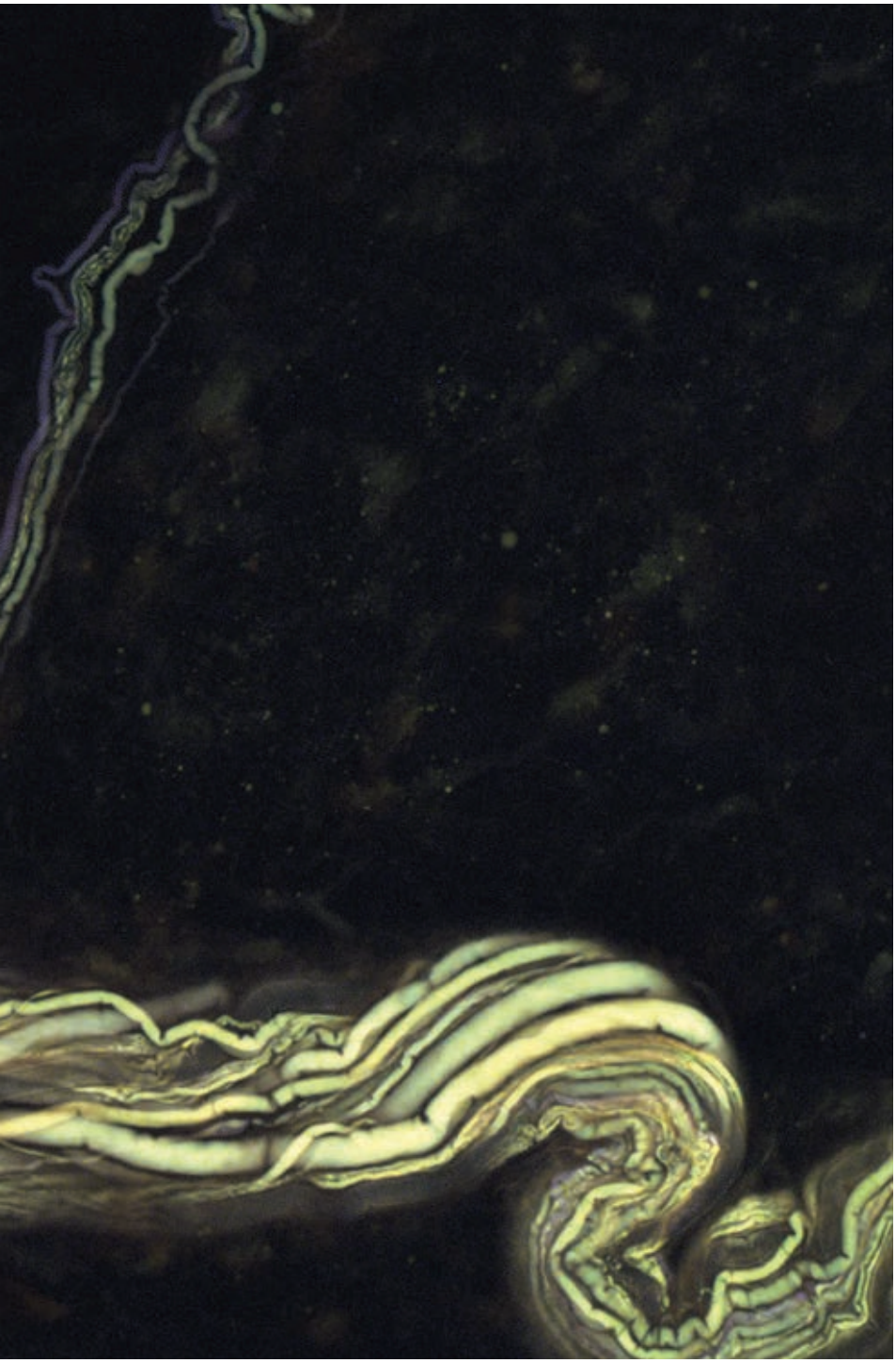
This image, reminiscent of a French impressionistic painting, contains little blue, green, and purple leaf-like structures, which are the iridophore cells, responsible for the squid's ability to change its patterns and colors. Iridophores are organized like overlapping plates, and depending on how they are spaced in relation to one another, they reflect different hues. The tendril-like branches are the nerves, transmitting information from the brain to tell the iridophore how to position itself. "These pictures are only a keyhole view of what's actually there, and that's another tantalizing part of it. Each time I make a new preparation, I'm going to see new things," says Senft.



COLOR WHEEL

A squid embryo seen through a microscope. Some of the colors are due to the laser reflecting off material in the creature or to dyes Senft injected into the tissue. The red and yellow dots are the chromatophores, responsible for the squid's red, yellow, and brown hues. Although they're too small to see here, there are muscles surrounding the chromatophores, like spokes on a wheel, which contract and relax, changing the diameter of the chromatophore, determining the sizes of the spots.





BRAIN POWER These cable-like bunches are nerves, each composed of little wires called axons. The axons branch to different targets simultaneously, such as the chromatophores and iridophores. When a single neuron fires it can change a field of chromatophores and turn the squid a flaming red color or make it as speckled as a quail's egg. "I've seen dozens of these [axons] under the microscope and some of the branching patterns are really stunning geometries," says Senft.

NERVE CENTER A look inside a squid hatchling, whose body is mostly transparent. The reddish, hot pink tube in the center is the "pen," the hard structure that gives rigidity to the squid's otherwise soft body, and behind it is a partial view of the digestive system in dark green. The black splotches are chromatophores. The yellow areas, stellate ganglia, are components of the nervous system. "They are the place where many inputs and outputs converge, and so it's like a little computer outside of the main brain," Senft says. "You can see where the nerves are going because they're the ghostly green lines that come out."

COMMUNICATION WEB Each black circle is a chromatophore and the illuminated vines shooting from each one are nerve fibers of an adult squid, which Senft colored with a special dye. "It gives you the sense of how much like a disorganized spiderweb all of this communication is," Senft says. Images like this one help him begin to understand the complexity of the squid's signaling system.

Out for Young Blood

Science has given new life to an old thirst

BY NATALIE COLEMAN

THE VAMPIRE LIVE ON, and cannot die by mere passing of the time," *Dracula*'s Abraham Van Helsing tells his colleagues. "He can flourish when that he can fatten on the blood of the living. Even more, we have seen amongst us that he can even grow younger ..."

The great gothic novel didn't invent the idea of rejuvenation through blood. It drew on a belief that persisted from the myths of ancient Greece through the early days of Christianity—and, remarkably, to the present day. As Van Helsing lays out his methods to capture and kill Dracula, he tells his companions they have a special power on their side, "a power denied to the vampire kind"—the power of science. In a remarkable irony, certain scientists in the past decade have taken the side of the vampires, offering evidence that blood from the young, when transfused into the old, may strengthen "vital faculties" and ward off elements of aging.

Stoker wrote at a time when science was countering widely held superstitious and religious beliefs. Is the modern-day resurgence of interest into the rejuvenating powers of blood good science working well, or a step backward into a familiar superstition?

EACH OF OUR BODIES course with a little more than a gallon of blood, from our blushing cheeks to the teal veins that branch across our arms. The earliest humans to see this vital liquid as a life-giving source were the ancient Greeks. Hippocrates, the Greek physician from 400 B.C. and the father of modern medicine, believed our bodies were controlled by four fluids called "humors"—blood, phlegm, and black and yellow bile. The humors were said to influence our personality, emotions, behavior, and age. The ancient Greeks saw the sanguine heat of blood to be so essential for life, that it was considered its very source.

The Roman poet Ovid, in 8 A.D., published the first instance of a revivifying transfusion. In his epic *Metamorphoses*, the witch Medea slits an old man's

throat and drains all the blood out of him. She fills his "ancient veins with rich elixir" that revives him. The elixir is not blood but root, herbs, seeds, flowers, and the like. But the point remains: The "new blood" grants him the "vigor of bright youth."

The Greeks weren't far behind Ovid's account. After gladiator duels, spectators would pour into the stadium in a mad dash to drink the fighters' gore, desperate to consume the strength and bravery that must have been flowing through their veins. In 77 A.D., Pliny the Elder observed that epileptic spectators were like "wild beasts" upon the arena, Pliny the Elder observed in 1 A.D, rushing "to quaff the warm, breathing, blood from a man himself." They put their lips onto a gladiator's wounds, hoping to suck a cure straight from his veins.

By the 15th century people were trying more direct methods. When all attempts to revive Pope Innocent VIII from his stupor had failed, a physician with a concerning lack of qualifications named Abraham Meyre brought three young shepherd boys to the Pope's bedside, each about 10 years old, selected as sacrifices and bought for one ducat a piece. Legend has it he drained some of their blood into the Pope, and then transfused some of the Pope's blood into them. Shortly after, all four died.

Nevertheless, the myth of blood rejuvenation persisted. In the late 16th century, the German physician Andreas Libavius wrote that transfusing the blood of a young, healthy person into the vessels of a sick elder could "bring him the fountain of life and drive away all languor." In the early 20th century, young blood's role as an antidote for aging informed the philosophy of Alexander Bogdanov, a Russian physician, polymath, and early Bolshevik. He understood transfusing young blood to be an almost metaphysical experience. It was an ambrosia capable of rejuvenating even the most exhausted human body. His philosophy manifested into a fictional 1908 tetralogy laying out an ambitious vision of a utopian communist society on Mars. His Martians lived to be more than twice the age of Earth's humans, and to achieve this prolonged lifespan, they transfused themselves with young blood, prolonging youth for hundreds of years. He imagined a large-scale concept of the "blood brother," where all members of society shared their blood communally.

By the spring of 1928, Bogdanov had received 11 transfusions in total, convinced that they increased his cognitive abilities, his eyesight, and even reversed some of his baldness. After trading one liter of his blood for a liter from a 21-year-old boy later that year, Bogdanov died from his twelfth and final transfusion.

IN *FAUST*, GOETHE WRITES that "blood is a juice of rarest quality." But for most of history humans had no idea what that quality actually was. As early as the 17th century, scientists began to understand that blood was composed of distinct components, each of which had a distinct function in the body. But it took the advance of modern medical science to pinpoint those functions and how they could be used for transfusions.

If you spin blood in a centrifuge, it will separate into three layers. The bottom layer is composed of red blood cells, which transport oxygen from the lungs to the body's organs. The top layer, a translucent pale yellow, is the plasma, which contains clotting factors, proteins—which transport vitamins and minerals throughout the body—and antibodies, proteins that work with the immune system to fight infection. Without plasma, other cells would have no fluid to travel through. In between those two layers are pale yellow platelets and white blood cells, which help the blood to coagulate and provide immune defense, respectively. Any of these elements can be replaced during

LE VAMPIRE / PHILIP BURNE-JONES / WIKIMEDIA COMMONS

In a remarkable irony, scientists in the past decade have taken the side of the vampires.

a blood transfusion.

Following the previous centuries' messy attempts at transfusions between dogs, lambs, and eventually humans, the 20th century saw a revolution in the way blood was controlled, stored, and used as a medicine. In 1901, Austrian physician Karl Landsteiner discovered the first three human blood groups, A, B, and C—which later became O—and went on to win a Nobel Prize for his work. A year later, two of his colleagues, Alfred von Decastello and Adriano Sturli, added the fourth blood type, AB. Far beyond the early days of transfusing the blood of friends, family, and whoever was standing by, doctors could now check the type of donated blood, matching it to their patients. These advances lay the foundation for manipulating and even manufacturing human blood for transfusions.

Spectators put their lips onto a gladiator's wounds, sucking the life straight from his veins.

The modern interest in blood renewal kicked off in the 1990s. That's when Michael and Irina Conboy, a researcher and an associate professor of bioengineering at the University of California Berkeley, respectively, began mulling one of the biggest questions in aging research: Why, when we get older, do the organs and tissues in the body seem to age together?

"Well, the first question to ask is what's in common to all tissues, and that's the circulatory system," says Michael Conboy. Through a series of veins and arteries, the body circulates the blood. Because the circulatory system delivers all of the nutrients to the tissues in our body, doesn't that make our blood the main culprit? "Our idea was, what if we took a mouse, took out all the old blood and gave it young blood," he says. "Would that make it young again?"

When we get older, there is more inflammation in the body, which comes from an increase in inflammation-type signals in the blood, Conboy explains. Another important change with age comes from cellular senescence, when the cells in the body stop dividing. Senescent cells accumulate in our tissues and organs as we age, which can lead to cancer, disease, and other age-related declines. To test whether these negative changes could be reversed, the Conboys turned to mice.

In 2005, working with a team of researchers at Stanford, the Conboys published a study in *Nature* showing the effects of heterochronic parabiosis—splicing together the circulatory systems of two animals of different ages—which in most cases are mice. The researchers detached the side flanks of skin from a young and old mouse and sutured them together like conjoined twins. The young mice were around 2 to 3 months old, and the older mice were 19 to 26 months. In human years, it was like hooking a 20-year-old up to

THE TRANSFUSION OF HUMAN BLOOD / JOSEPH ROUSSEL / WIKIMEDIA COMMONS

a 70-year-old. As they healed into each other, their two circulatory systems fused together—the blood from one flowing seamlessly into the veins of the other.

The older mice were were able to bounce back more quickly after injuries, and showed a proliferation of cells in the liver and hippocampus—which is usually the opposite in older mice. The effects of aging seemed to have been reversed—although it wasn't clear that the effect derived just from blood. The circulatory system of the older mouse also had access to the younger mouse's organs, which could help regulate the metabolism of the older mouse, help it to heal more quickly, and even supplement it with proper hormones and nutrients. There were other contingencies resulting from being attached by skin. Sometimes, the young mouse would even drag the older mouse around the cage, giving it more exercise.

In November last year, Michael and Irina Conboy published a study in *Nature Communications* examining the effects of a single exchange of old and young blood between two mice, mixing their blood equally. In this case, the mice were not conjoined as they were in the 2005 study. The Conboys developed a new device that could connect and disconnect the mice at will, which eliminated the effect of sharing organs. The technique was essentially a single mutual transfusion between the mice. That way, the results would show only the effects of the blood exchange, rather than the shared circulation system.

Again, the older mice saw immediate improvements to muscle regeneration and liver health—the fatty deposits nearly disappeared, mirroring the organ of a young mouse—but the Conboys discovered in later research that the old blood was far more inhibitive than the young blood was beneficial. Tellingly, when they mixed together equal parts of old and young blood, the result did not look like middle-aged blood. "It just looks like old blood," Conboy says. Old blood severely obstructed the young mice's formation of brain cells, led to an increase of fatty deposits in the liver, and even led to poorer performances during strength tests, where they were hung upside down from a mesh wire. "Again the old animals saw a dramatic improvement, but what was even more interesting to us was the deficits in the health of the young animal from the old blood," Conboy says. "After those results, we weren't all that interested in young blood as a medicine. We need to figure out what in old blood is so detrimental."

Conboy thinks one culprit might be TGF beta, a family of proteins that helps control many of the

The effects of aging seemed to have been reversed—although it wasn't clear that the effect derived just from blood.

THE FOUNTAIN OF YOUTH / LUCAS CRANACH THE ELDER / WIKIMEDIA COMMONS

body's cellular functions, including cell growth, differentiation, and a signal to shut off a cell's growth. As we get older, the amount of TGF-beta type proteins in the body increases, releasing a pro-inflammatory signal to the cells that impedes healing and blocks the proliferation of stem cells. If we could instead give cells the proper growth stimulus and override negative factors such as TGF beta, it might be possible to keep the cells growing, restoring the old body's tissues.

"That's what we see in the muscle of old mice after the transfusion; it's able to regenerate just as well as young mice," Conboy says. "If we could intervene and give more youthful signals to the cells, it would be more than adequate to rejuvenate the tissue." The real impact of these experiments, then, may be a new understanding of why old blood is so deleterious, rather than reason to inject young blood.

IN LUCAS CRANACH THE ELDER'S 16th-century painting *The Fountain of Youth*, haggard women clamber into the flowing waters of a glaucous pool. They frolic, they become softer, more beautiful, and emerge from the other end of the pool revivified, the bodies of their youth restored.

That might be the very vision of a new cohort of medical entrepreneurs promoting the virtues of young blood. One of them is Stanford neuroscientist Tony Wyss-Coray, who has worked to isolate elements in youthful blood that he says can revive aging bodies. He's started a company called Alkahest dedicated to reversing some of the degradations of Alzheimer's disease by injecting patients with small doses of plasma from young donors. "Now, I don't think we will live forever, but maybe we discovered that the Fountain of Youth is actually within us, and it has just dried out," Wyss-Coray said in a TED talk. "If we can turn it back on a little bit, maybe we can find the factors that are mediating these effects, we can produce these factors synthetically, and we can treat diseases of aging."

Nobody has capitalized on the parabiosis studies more than Jesse Karmazin, a Stanford-trained physician in California, at least judging from the amount of media coverage he has courted and received. Karmazin has launched his own startup called Ambrosia—after the immortal food of the gods—that is running a trial to test the effects of blood infusions from the young into the old. (Following a rumor that PayPal cofounder and venture capitalist Peter Thiel was interested in Karmazin's trials, the TV show *Silicon Valley* spoofed the process, featuring obnoxious tech giant Gavin Belson getting transfusions from his "blood boy.")

Ambrosia's ongoing trial admits people over the age of 35—of more than 100 patients, the youngest patient is 39, and the oldest is 92—to its clinics in San Francisco and Tampa. Patients pay $8,000 to participate, which covers the costs of the plasma, transfusion services, and blood tests.

The patient-funded trial doesn't target any specific disease—rather, Karmazin hopes to target multiple diseases at once. Some entrants suffer from conditions such as diabetes, heart disease, and Alzheimer's disease. "A fair number of patients are younger and healthier, and they want to stay that way," Karmazin says. "And I think that's easier. In theory, it should be easier to keep someone healthy than to reverse a disease, but it does seem to show a potential for both."

Karmazin says the patients report immediate results, starting as soon as the transfusion does. Patients, he says, tell him they feel stronger, that the visibility of their wrinkles decreases. They can immediately resume normal activity afterward, and some report lifting more weight at the gym.

"These results are still preliminary, but they're showing some really strong changes," Karmazin says. In the blood tests, he reports seeing three changes in particular. First, there is a decrease in the number of amyloids, which can form plaques implicated in diseases like Alzheimer's and Parkinson's. There is also less inflammation, and lower cholesterol—a sign of cardiovascular health.

Although the results are drawing new clients to the trial, Karmazin did not use a placebo or double blind methods, which are both standard practice for medical tests. His studies have also not been peer-reviewed or published. Because of this, scientists in the community have been critical of his work. Even if young blood were proven to posses restorative qualities, would the benefits be worth the potential risks of an unnecessary transfusion?

"The number one thing I'd be concerned about would be the risk of spreading disease," says Alan Mast, a senior investigator at the Blood Research

THE TRANSFUSION OF HUMAN BLOOD / JOSEPH ROUSSEL / WIKIMEDIA COMMONS

Institute at the Blood Center of Wisconsin, and an expert on transfusion medicine with the American Society of Hematology. Mast stresses blood transfusions today are safer than they've ever been. Still, he says, "To me, it's a risk. Is it really worth it if you don't need the transfusion?" Older patients prone to congestive heart failure could also be at risk for volume overload from a transfusion, which could make their heart condition worse.

Epidemiological studies are also contradicting the early reports of transfusion benefits. Gustaf Edgren, a hematologist and associate professor of epidemiology at the Karolinska Institutet in Sweden, studied a large database of blood transfusions and donations in Sweden and concluded that the age of blood donors have no correlation with recipient mortality, the opposite of what you'd expect if young blood had a rejuvenating effect. (The patients he studied had received transfusions they needed to survive.)

Edgren sees Karmazin's methods, in particular, as "unethical and potentially quite dangerous." Without any placebo to compare against, Edgren says, "the study is scientifically disinteresting." He doubts whether Karmazin's results can be taken seriously since there is no way of knowing if the reported benefits derive from the age of the donor blood, the plasma transfusion itself, or some other variation that was not experimentally controlled.

Edgren says the claims that young-blood transfusions can arrest aging remain premature. "My opinion as a clinician is that humans die much more from disease than from mere old age," he says. "There's so much hype surrounding this, that they're just not advancing the field. It's not going to do any good for the patients, and it's not going to do any good for our scientific understanding of aging."

Edgren is hopeful future research can move toward firmer conclusions by more closely emulating the techniques in the mouse studies. "I'm not saying there couldn't be such an effect from the young blood also in humans, but to test this we need to design studies for humans that mimic the mouse models much more closely."

In the meantime, scientists continue to buy and sell millennial blood for injection into the old and hopeful. While we don't treat young blood as the elusive ambrosia of legend, after centuries of scientific advancement it is remarkable how attached we are to the same story.

NATALIE COLEMAN is an editorial intern at *Nautilus*.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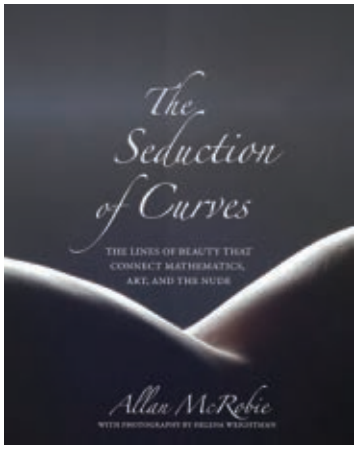

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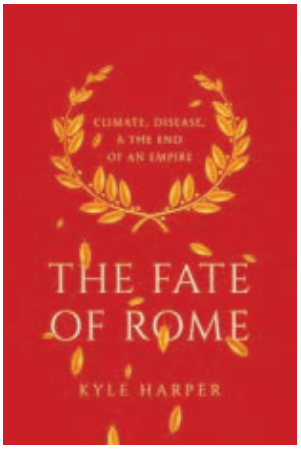

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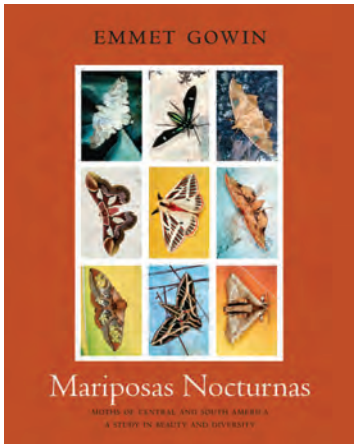

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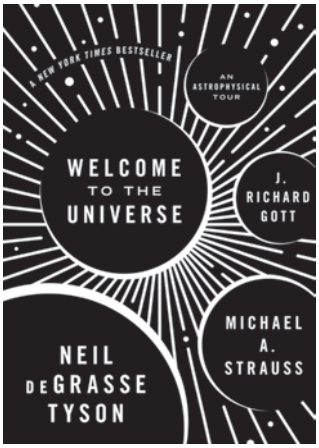

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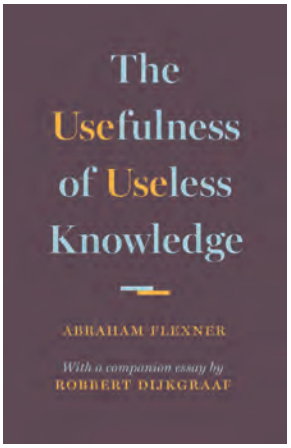

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Issue Index

22

SEPT/OCT 2017

21

JULY/AUG 2017

20

MAY/JUNE 2017

19

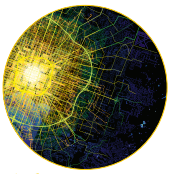
MAR/APR 2017

18

JAN/FEB 2017

17

NOV/DEC 2016



16

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12
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Mark Moffett

The author of Adventures with Ants *reflects on the themes in* Nautilus

INTERVIEW BY KEVIN BERGER

THE HIVE

In equatorial Africa I've encountered raids of army ants 100 feet wide that form a solid mass along their advancing front. Picture a giant fan moving toward you at 20 meters an hour. It sounds like rain because some of the millions of ants fall off vegetation as they grab onto prey. A constant pitter-patter. You can outrun them but the trick is knowing which way to go. The ants are dark and so you might not see them right away. Many animals head in the wrong direction and get caught in the net-like fan. The ants, which have knife-blade jaws that cut flesh, pull the animal down. Now, most ant species send scouts to check out the hunting grounds in advance, and dispatch troops according to the information that comes back. Not army ants. The whole kit and caboodle departs as one without any advanced planning or leader. No saying what they're going to find. But the advantage is the instant they find it, they're ready for the kill—the ant version of shock and awe.

MONSTERS

It's difficult for me to call anything a monster because I find novelty in nature exciting. I don't see dysfunction. Once while hiking in a palm grove in Sri Lanka, I looked down to see an astonishing creature on my bare arm. It walked along with a methodical slowness that bespoke intelligence, something like one of those giant tank-like robots in *Star Wars* battles that shoot missiles from their heads. Except this thing had a half-inch leg span. Most people would have freaked, and to most people it would have been a monster—at least a miniature one. I tried to get it off my skin, but it was tough as a nail, with clingy feet that made grasping it nearly impossible. Only later did I figure out it was a wingless fly, an ectoparasite of the flying foxes in the palms overhead that lives, vampire-style, by sucking the blood of bats. Still, it did me no harm, and my response wasn't horror, but a feeling of joy and wonder. I think people who are open to experience probably experience fewer monsters than people who have to have their coffee at 9 a.m. sharp. A safe, punctual life is the dwelling place of monsters.

ILLUSTRATION BY FRANCESCO IZZO