

NAUTILUS

FREE WILL IS BUNK
Or is it? The debate rages

NIKOLA TESLA'S PIGEON
A love story

FEMALES DROVE EVOLUTION
Setting the record straight



The Hero's Tale

SEEING YOUR LIFE AS A HEROIC JOURNEY p.22



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Soaring

BY KATHERINE HARMON COURAGE

READING A TRULY GREAT STORY brings a rush of lightness in the chest, a feeling, almost, of soaring.

It was the feeling I had reading drafts of writer Amanda Geffer's story in this issue. I had written to her, out of the blue, after becoming enthralled by a fact I had read about Nikola Tesla. The inventor had uncanny insights about the workings and potential of electricity and energy. He also believed he had a telepathic relationship with a white homing pigeon. Might there be something there, I asked her?

After combing through thousands of pages of books and old newspaper and magazine articles, Geffer brought back a beautiful and strange story, one that traces the amazing period when advances in electromagnetism were enabling light, information, and even voices to appear out of thin air to people—a period of magical thinking that has unspoken resonances with our own. And like any great romance, her tale “Tesla’s Pigeon” ends in destruction, and a deepening mystery.

This is one of the great privileges I see entering my second year at *Nautilus*: the opportunity to give great writers a small waypoint and turn them loose to chart an unexpected path there—and back.

Our cover story, “We Can Be Heroes” shares a similar origin story. This one takes off from a small paper citation from a social psychology journal, which our editor, Kevin Berger mentioned to the wide-ranging journalist Adam Piore. From that call, Piore’s response is an expansive epic tracing the tales of heroes he has encountered over his long career and their ability to find resilience from the depths of tragedy through the healing power of narrative itself.

And then there are the stories that arrive, unbidden, at our doorstep, nearly fully formed and wildly transformative.

When the great science writer Philip Ball was facing the publication of his latest book, *How Life Works* and his own intensive cancer surgery—on the same day—he turned to us to publish his moving essay about it, entitled “How Life Really Works.” In a well-ordered whirl, he brings us through the latest thinking about the origin of life, its meaning, and the meanings left in its wake when it ends. (Long-time science journalist John Horgan called the piece, “science writing at its most sublime”; I couldn’t agree more.)

Sometimes the gift comes from a stranger. This was the case with “The Happiest Man in the World.” That subject line appeared in my inbox, from an unknown sender. It turned out, the accomplished writer Pagan Kennedy brought the story to *Nautilus* based upon the suggestion of another celebrated contributor. The story’s premise—that perhaps those who suffer from psychotic delusions that bring their lives a central purpose might be allowed to keep their un-realities—is told with such vividness and grace, it was an easy *yes* to invite her and her work in.

These and the other great stories in this issue offer a liftoff from the daily, cursory myopia. Then, suddenly a soaring, in a thrilling phrase—“a feeling that the universe had cracked open and that a brave new world was spilling out,” as Geffer writes—a new perspective—“life is the spinning itself, while it lasts,” as Ball notes. Built on the rigor of high journalistic standards, these stories then carry us aloft with the seamless ease of a flock of birds taking flight, alighting in unexpected places. Before returning us home again, ever so slightly changed.

Happy soaring.

KATHERINE HARMON COURAGE is the deputy editor at *Nautilus*.

The Art of Saving the Ocean

How Island Restoration
Saves People & Nature



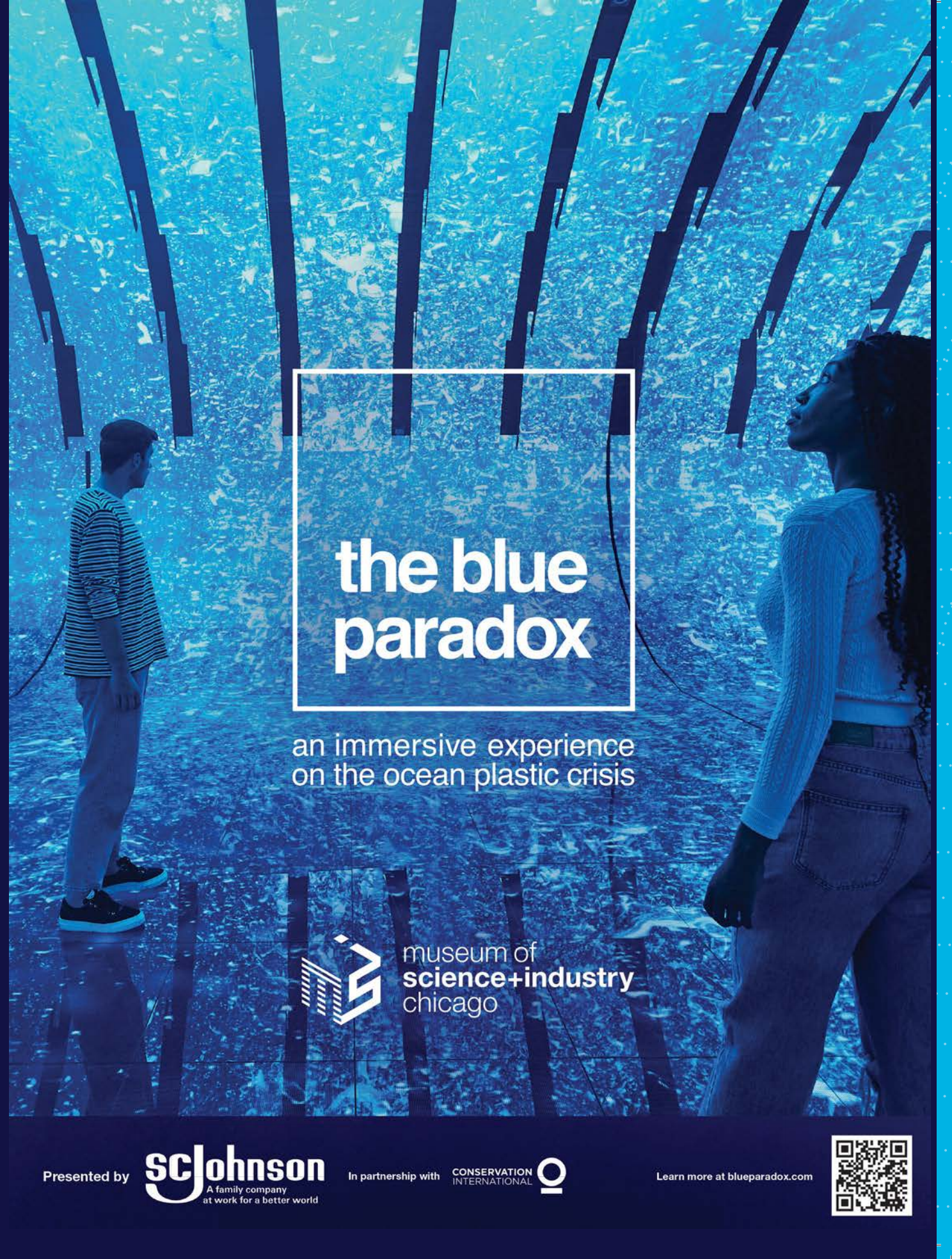
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THE PORTHOLE

Short sharp looks at science

PSYCHOLOGY

The Virtues of Not Knowing

I AM GOING TO SHOW YOU some pictures. Tell me whether each is more like a dog or a cat.” With these brief instructions, a pioneering University of California, Berkeley psychologist began giving people so-called tests of perception that were in fact extraordinary barometers of their capacity to relish the twists and turns of life.

Participants were shown a series of drawings of an animal that at first distinctly resembled a cat but then, bit by bit, with a tweak to an ear or a broadening of a muzzle, turned fully canine. The middle pictures were indeterminate, and for some, that proved unnerving. Again and again, these participants refused to surrender the safe harbor of their first answer until the sequence was nearly complete. They showed “a preference to escape into whatever seems definite,” wrote the researcher, Else Frenkel-Brunswik.

The famous cat-dog experiments were part of a postwar search by some of the world’s leading scientists for the roots of authoritarianism and prejudice. What Frenkel-Brunswik discovered for her part was a key signature of the closed mind: intolerance of uncertainty.

Reaping the promise of not-knowing depends on a simple rubric: whether people are intent on eradicating uncertainty or are willing to stay open to it and so to a situation’s subtleties and complexities. This is a decision made in

the moment yet one that also emerges from an individual’s personal comfort zone for uncertainty.

“Being uncertain means that I lack confidence.” “There is really no such thing as a problem that can’t be solved.” “I should be able to organize everything in advance.” These are statements drawn from the “Intolerance of Uncertainty” and “Tolerance for Ambiguity” tests, classic assessments that have been attracting new attention as tools for unlocking the upsides of not-knowing. (Ambiguity, the state of being inexact or open to multiple interpretations, is a source of uncertainty.) In essence, the tests measure the degree to which people view being unsure as a challenge or as a threat, a distinction that affects how well we learn, argue, explore, invent, and solve problems.

Those who shun the indefinite tend to see the world in shades of black and white, ignoring the gray. They are





prone to jump to answers and are distressed by chaos and surprise. Their “cognitive map” is narrowed to “rigidly defined tracks,” wrote Frenkel-Brunswik. In contrast, people who operate on the other side of the scale are more likely to be curious, flexible thinkers who revel in complex problems and in new experiences from living abroad to trying a new delicacy. They may even be in better charge of their minds; evidence suggests that such thinkers have more gray matter (i.e., neural volume) in brain regions related to executive control.

In the study of the mind, a tolerance is a tendency, not a fate. We are all more or less prone to be introverted or outgoing, impulsive or reflective, and to welcome the opportunity of incertitude or not. A refusal to not-know isn’t a guaranteed mark of fascism or bigotry any more than someone who dislikes parties is automatically a full-on recluse. (And while political conservatives are a little more reluctant to embrace uncertainty, the well-publicized link between these two complex concepts is weak; many liberals detest surprises, and no small number of conservatives revel in change.)

We all have a personal appetite for not-knowing, but the real news is that this leaning is malleable. Situation and context matter; under time pressure, almost everyone’s eagerness to race to a conclusion deepens. At the same time, through practice and a bit of effort, we can bolster our capacity for lingering in the gray spaces where cognitive treasures abound. It is possible to move the dial.

Picture a laboratory experiment that brought together pairs of strangers with opposing political views for a brief online back-and-forth on a controversial topic such as abortion or gun control. The interactions that unfolded in the 2016 study were just the kind that so often go quickly awry. This is the moment when the cognitive mismatch that confronts us isn’t a mystery virus or a trade policy shift but another person with a wholly different view, an opponent we say. The potential for “conflict processing” awaits.

At the outset, half of the pairs were coached to take on a highly competitive, point-scoring mindset. The other duos were told to cooperatively learn as much as they could from one another. In 15 minutes, this slight difference in stance shifted the participants’ approach to the world. The pairs of strangers who were gunning

We all have a personal appetite for not-knowing.

to outperform one another turned more absolutist, that is, lovers of sureness in learning and knowledge. They became more likely to believe that there was one unerring truth to the matter and that they held it, like a rock that they could seize and defend.

In contrast, those who had been primed to learn became more evaluative. They began to see knowing as inherently uncertain and as something best forged from multiple viewpoints. “I can absolutely see that point,” said one participant. They were no less confident in their views; contrary to what we might expect, having the courage to tolerate ambiguity is associated with assertiveness. But by being open to new, challenging information, they grew willing to examine and modify their position. They treated their understanding as akin to an evolving yet durable tapestry, its strength deriving from its very suppleness and mutability. From such a vantage point, more skillful and persuasive arguments are made.

No one seminar or script can transform us into virtuosos of not-knowing. “We don’t have a home-run magic bullet for this,” a leading scientist of uncertainty chided when I pressed him for an antidote to our fear of the unknown. We can’t “inject all this, bottle it, and put it into some easy intervention,” said Paul K. J. Han, a senior physician-scientist at the National Institutes of Health. One-shot fixes are the pipe dreams of an instant-answer age, he was reminding me.

Still, neither should we ignore the myriad chances that await us each day to open our minds to uncertainty—and to its remarkable potential.

—Maggie Jackson

This essay is excerpted with permission from *Uncertain: The Wisdom and Wonder of Being Unsure*, published by Prometheus Books.



ARTS

Fishing Gear on the Fashion Runway

WHEN MARION GAEMERS AND LYNNETTE GRIFFITHS turned on the black lights in their studio not long ago, they were pleased. The discarded fishing gear they were using to create their latest work of art luminesced, giving it a ghostly oceanic glow. The wearable sculpture, which has 500 silvery sardines worked into its skirt, is meant to conjure an imaginary queen who lives beneath the sea—and to warn of the dangers of ghost nets.

They call the work the *Birth of the Babel Fish*. It's loosely inspired by Douglas Adams' *The Hitchhiker's Guide to the Galaxy*, in which a fictional species of fish called the babel fish tour the cosmos, helping to translate the various languages spoken by cosmic hitchhikers so they can communicate. Gaemers and Griffiths crafted the gown as an entry to the 2023 World of Wearable Art competition to spread the word about the threat posed by rogue fishing gear, also known as ghost nets, to all the living things in the ocean.

The pair of artists have been creating environmental sculptures out of lost netting and fishing gear for a decade, and together run the Ghost Net Collective in Queensland, Australia, founded in 2020. These ghost nets ensnarl and kill ocean wildlife, posing a massive threat to biodiversity and marine ecosystems. Some 1,500 Australian sea lions die every year due to entanglement in fishing nets, for example. Ghost nets also attract other debris, coiling into leviathans that become a hazard even to shipping vessels. The problem has grown over time as fishing gear is increasingly designed with synthetic materials for durability. One 2018 report estimated that ghost nets, lines, and ropes accounted for almost half of the plastic found in the Great Pacific Garbage Patch.

Some ghost nets inevitably wash up on shore, and Gaemers and Griffiths collect them during beach cleanups. The larger ghost nets they use in their art works come to them from Tangaroa Blue, a nonprofit organization based in Western Australia that monitors the



MARINE QUEEN

Artists Marion Gaemers and Lynnette Griffiths spent five months crafting the babel queen's gown by hand. Here, Val Schier, former mayor of the Cairns Regional Council in Queensland, models it on the beach and in the studio.



out kits with ghost netting and instructions for how to weave marine critters to participants all over the world. They

ask that their collaborators send the pieces back to them, and incorporate them as details into their larger projects, thus spreading the ownership of the installations and helping to educate the public about ghost nets. Volunteer collaborators created all of the sardines in the babel fish skirt, they say. "Each sardine takes about 22 minutes to sew," Griffiths told me.

The *Birth of the Babel Fish* is a singular creation, weaving together the quirks of the two artists. Gaemers describes herself as "a science-fiction enthusiast," a big-time fan of *The Hitchhiker's Guide* and television series like *Doctor Who*, whereas Griffiths has long loved

impacts of marine debris along the coastline. Griffiths and Gaemers work all the material by hand, first hosing it down to remove sand and other rubble and then sorting the pieces by color. Once the ropes are detangled, they "deconstruct" them into threads and finally "felt" them into a fabric, says Gaemers. The fabric is woven into the sculptural pieces, using twining and plaiting techniques borrowed from basketry.

It's arduous work: Griffiths and Gaemers spent five months crafting the babel queen's gown by hand. But they had help, too: Most of the larger installations are completed collaboratively. Gaemers and Griffiths send

the world of fashion. The babel queen gown incorporates influences from the Elizabethan period, Griffiths says, a heyday of maritime exploration.

"We want people to be able to touch our work," Griffiths told me. To the artists, ghost nets are a symbol for global environmental problems writ large, which generally lurk out-of-sight and out-of-mind. "The nets are silent, deadly killers, and through what we do in our work, we want to make visible the hidden pollution." The *Birth of the Babel Fish* places that abstraction into a human context.

—Elena Kazamia



GEOSCIENCE

Earth's Core Has a Gas Leak

IN THE TURBULENT FORGING of the early Earth, density was destiny. Heat from asteroid impacts and radioactive decay turned a mass of primordial rubble, held together by gravity, into a seething, molten orb. In this feverish state, the matter that makes up the Earth separated into distinct layers; the densest materials sank, forming an iron-nickel core, while lighter silicate matter rose to form the rocky mantle.

Geologists have long assumed that these layers were permanent—and that no *physical* matter could cross the ancient boundary between Earth's core and mantle. A paper published in *Nature* in October challenges this view, providing evidence that the core may leak gasses stored there since the formation of the planet “up” into the mantle—and that these gasses can find their way, via volcanic rocks, to Earth's surface.

Although it begins just 20 miles beneath our feet and constitutes more than 80 percent of the planet's volume, Earth's mantle is a wild and uncharted place. Our deepest drill holes have never reached the mantle, and inferences about its makeup and roiling motions come from indirect sources, like earthquake-generated seismic waves that rumble through it, revealing it to be solid, though languidly flowing, rock. Other clues come from the chemistry of basaltic lavas, high temperature magmas which, when they erupt, have a viscosity close to that of ketchup. These lavas are generated by the partial melting of the mantle, and erupt through vents and volcanoes where the Earth's crust—its uppermost layer—is thin, mainly in the ocean.

In the 1960s, soon after the emergence of the theory of plate tectonics—which explains global patterns of volcanic and seismic activity—geologists noticed subtle differences in the chemistry of basaltic lavas released from sites like Iceland, known as mid-ocean ridge basalts or MORBs, versus those from places like Hawaii, called hotspots. MORBs lie along underwater volcanic ridges, while hotspots are areas of the Earth's



mantle from which isolated columns of hot magma rise, forming volcanoes on the overlying crust.

In particular, the chemistry of Iceland-type MORBs suggests that these lavas originate in a shallow mantle source. In contrast, the chemistry of Hawaiian-type hotspot basalts suggests they come from a deeper mantle source. Although the mantle churns itself through convection—the density-driven process whereby cold rock sinks and hot rock rises—many geoscientists believe that the upper and lower mantle churn separately, intermingling only via the hotspot plumes, or columns of magma, that rise from depth. In this view, pockets of “original” material—unchanged by melting, or other geological processes such as subduction, which recycle parts of the Earth's crust—could persist in the deeper parts of Earth's mantle, even after 4.5 billion years.

This idea of an upper mantle chemically distinct from the lower mantle has generally been supported by studies of noble gasses—like helium and neon—trapped in tiny amounts within mineral crystals in basalts. In particular, scientists have looked at concentrations of two helium isotopes, ^4He and ^3He . Whereas ^4He is more abundant in both rocks and the atmosphere, the much rarer ^3He is generally understood to be gas from the beginning of the world. In previous



It's generally understood to be gas from the beginning of the world.

studies, researchers have found that upper crust MORB basalts typically have more ^4He and primordial hot-spot basalts have more ^3He .

The new study, however, rewrites this tidy view of the mantle and its helium budget. The researchers found that basalts from Baffin Island, in Canada's Arctic Archipelago, though related to a hotspot, have MORB-like chemistry, and yet have higher $^3\text{He}/^4\text{He}$

ratios than any previously measured—higher, in fact, than any plausible primordial mantle values. While the researchers acknowledge that there may be more than one way to explain this unexpected combination, the simplest scenario is that MORB-type ocean crust sank to the base of Earth's mantle, where it was infused with primordial ^3He seeping out of the core. Some of this hybrid material then made the long ascent up to Baffin Island.

This is a radical new view of Earth's mantle and core as open rather than closed, where rocks from the crust may sink through the mantle and mingle with matter from the core—and then return to the surface with news of their journey to the center of the Earth.

—Marcia Bjornerud

ARTS

Our National Parks in the Quiet of the Pandemic

ON MY FIRST HIKE through Olympic National Park one evening this past summer, I was so overwhelmed by the primordial textures and deafening hush that I had the urge to lie down on the trail just to collect myself. It was dusk in northwestern Washington State, and the light was blue and shadowy as I crept up an entirely empty path through the rainforest. The moss covering every branch and trunk, dripping in long ringlets toward the forest floor, gave the trees the appearance of hungry ghosts. Every turn in the path seemed to offer a new twist in a visual fairy tale.

Something about moving through a wilderness landscape, one enlivened by the most elemental forces, more ancient than humankind, is uniquely transporting—even a wilderness that has been heavily shaped by human architects for more than a century, as our National Parks have been. The cliché rings true: “Nature” offers a balm for modern life. Even at the height of the pandemic, when the whole world seemed to go into COVID-19 lockdown, a surprising number of people piled into vans and RVs—and sought the comforts and thrills of our most treasured wide-open spaces.

Photographer Andy Katz was one of them. In 2020, rather than hunker indoors working on a retrospective



of his work, the 70-year-old photographer decided to go full nomad and pursue a project he had been considering for a decade: A book of photos of the National Parks of the United States. Within 24 hours, he bought himself a campervan and two days later was on a flight to Denver to pick it up. His first stop was Rocky Mountain National Park. Then he hit the road for three years. The resulting book, *A Walk in the Park*, is a gorgeous contemplation of the majesty of the country's wilderness captured during a time of widespread confinement.



Katz's plan was very simple: Visit all 63 National Parks and photograph what he found beautiful there. He knows he wants to photograph a scene when the light is doing something spectacular. "The light is the glue," he says, what tunes the frequency toward awe. Katz's three-year tour of the parks left him with a feeling of pride. "They have long been revered as America's greatest idea," he says. Of course, communion with these lands was sacred to the cultures of many Indigenous people, long before the wilderness was organized into tidy chunks for tourists to explore. Says Katz, "We can all agree that we live in a beautiful country if we can't agree on anything else."

—Kristen French

Photos by Andy Katz

ENVIRONMENT

Sand Mafias Battle for the New Gold

IN NOVEMBER, TWO MAFIA GROUPS in northeast India exchanged gunfire—and torched a half dozen earthmover machines—in a war over a natural resource. They weren't battling over diamonds or oil: The groups were both trying to get their hands on sand.

Sometimes called "the new gold," sand is the second most exploited natural resource in the world after fresh water. The world uses about 50 billion tons each year—twice the amount created annually in nature—and demand continues to grow. At the current rate, experts say we will run out of sand by 2050.

That's because sand goes into nearly everything people build: cement, concrete, roads, glass, and even the silicon chips in our laptops and phones. "Without sand, there's no modern civilization," says Vince Beiser, author of *The World in a Grain: The Story of Sand and How It Transformed Civilization*. "Our cities are literally built out of sand: Every apartment, every office tower, every shopping mall, every road is made with sand."

The intensity of demand, coupled with weak regulation, has made sand mining an easy target



for mafias, especially in Cambodia, Kenya, Nigeria, and India. Almost all sand mining operations in these countries are illegal, says Arpita Bisht, a researcher at The International Institute of Social Studies, in The Netherlands, where she studies resource extraction. India likely has the highest incidence of mafia violence and illegality related to sand extraction, she says, though it's challenging to quantify because of the lack of government tracking and reporting. Journalists who report on sand mafia activity often put their lives at risk: In one of the most extreme cases, a journalist was burnt to death in 2019 for his consistent reporting on sand mafia activity in northern India.

"There's not nearly enough corporate responsibility around it," says Bisht. The lack of oversight is partly due to the fact that, unlike other mining resources such as oil or coal, sand is relatively easy to access, and because the biggest consumers are rapidly developing countries with weak environmental policies and enforcement. For example, less than 4 percent of the 80 million tons of sand that Singapore imported from Cambodia between 2009 and 2019 was documented.

Sand might seem like an inexhaustible resource—after all, our deserts are full of it. But desert sand is too fine to be used in construction materials. Though some of the sand used by industry comes from oceans, estuaries, and beaches, most of it derives from riverbeds. Sometimes miners will simply park a barge in the middle of a river and use a giant tube to suck up the sand like a straw and deposit it on their boats. But these sand straws often suck up plants and creatures living in the river, as well, and destroy their habitats. The churning of the river water can prevent sunlight from reaching aquatic plants that need it or even choke resident fish, and the depression of riverbeds can cause erosion and kill vegetation along riverbanks and floodplains.

In India's Kuls river, the already-endangered Gangetic river dolphin is losing habitat to wide scale sand mining. Similar ecological damage has been reported in the Mekong River, a boundary river in East Asia and Southeast Asia, where massive sand extraction operations have upended a biodiverse river ecosystem, Bisht says.

Illegal sand extraction also has massive social impacts. Damage to riverbeds can imperil local infrastructure such as bridges, and pollution from equipment



fuel spills can destroy fisheries and threaten water for drinking and for agriculture. Along a part of the coastline of Tamil Nadu in India, entire villages have been abandoned due to the threat of erosion. Mafias also threaten, intimidate, and abuse people living in the communities where they work—not just journalists, but farmers, NGO workers, community leaders, and even some local police officers. Hundreds of people have reportedly died in conflicts over sand in India, Kenya, and Nigeria.

For sand mining laborers, working conditions are dangerous. Drowning is a big risk. "In the case of Vasai Creek in Mumbai," Bisht says, "miners report that their fellow miners have sometimes got buried in underwater sand dunes and simply never returned from sub-creek mining operations."

Beiser points out that even though sand has built almost everything in modern life, few people realize the extent of its use—or the violence kicked up by its extraction.

—Katharine Gammon

ZOOLOGY

My 3 Greatest Revelations on "Curious Species"

1

NATURALISTS STILL USE METHODS COMMON IN THE 1700S

Naturalists have long had to look in odd places to broaden the scope of human knowledge. In the 1700s, they would frequent fish markets to find new specimens and cut open the guts of predators, like sharks, to locate deep-sea or



otherwise rare species. They harnessed both lay knowledge and the interconnectedness of life to enrich their understanding.

When I spoke to contemporary fish researchers for my book, *Curious Species: How Animals Made Natural History*, I learned they still do these same things: scrutinize the goods at fish markets and sort through fish bellies. In fact, some species that have only ever been formally documented once—including a brown subtropical eel called *Ethadophis merenda* and a species of snailfish from the Indian Ocean called *Paraliparis infeliciter*—were found in the stomachs of predatory fish. (It's no coincidence that the species name *merenda* means snack, and *infeliciter* bad luck.) Unwitting animal collectors have proven essential for finding hard-to-reach creatures. And these gory examples represent just a few of the many uncanny echoes between the 18th-century past and the present that I stumbled upon while researching my book.

2 MUSEUMS ARE THE NEW FIELD OF DISCOVERY

Writing this book led me to spend many hours in those corridors of natural history museums the public rarely gets to see: their specimen collections, whose holdings can number into the tens of millions at the larger institutions.

Far from serving as commemorative graveyards, these storehouses function as active research sites for scientists and harbor many a hidden gem for the historian, too. Biologists continue to discover new species among the cabinets and trays of old specimens by studying their morphology and genetics. That's how the olinguito—a small South American mammal related to raccoons—was described as a new species in 2013. The first indicator (at least to professionalized science) that it might

Contemporary researchers still sort through fish bellies to identify new specimens.

differ from other members of its genus, the olingos, came not initially from field encounters in its cloud forest habitat but from specimens stored in a museum.

There are simply so many specimens in these repositories that their expert keepers can't keep a mental inventory of every item in the collection. One curator and I were dumbstruck when we happened upon a roughly 300-year-old rattlesnake at London's Natural History Museum that was part of the collection of Sir Hans Sloane. Sloane, a one-time President of the Royal Society, died in 1753, after which his collections were assembled to found the British Museum. But his preserved animals were almost entirely annihilated by fire in the 19th century. And it was no accident: Museum staff set out to torch his decaying and, to their minds, unsystematic zoological holdings. Animal stragglers from his collection exist, but it's a bit like finding a needle in a haystack.

3 THE GOLDEN AGE OF NATURAL HISTORY HAD A DARK SIDE

The catacombs of natural history museums harbor hidden human stories, as well. In another vault—this one was literally a bomb-proof vault—I matched two dried fish specimens Carl Linnaeus received some 250 years ago to a letter written by Charleston, South Carolina-based physician and enslaver Alexander Garden.

Garden's letter to Linnaeus reveals the fish were collected and preserved by a man he simply calls a "black servant"—someone almost certainly enslaved, based on contextual clues. The 18th century was a golden age of natural history, but it often flourished by committing human horrors. Naturalists used enslaved labor to build their specimen collections, and they both abetted and benefitted from a colonial enterprise that killed millions of Indigenous people. Behind every specimen, modern or historical, there is very often a shadow story of how it came to find its way into the museum.

—Whitney Barlow Robles



Portrait of a Fractured Arctic

MARK URBAN WAS NOT in the Arctic to study ice. He was looking for fish—tracing their travels from lake to stream and back again, as they navigate their changing world. But at all hours, in the field and in his campsite, he could hear it. *Plink, plonk, plink.* Pebbles subsumed in ice thousands of years ago being released from previously frozen lake banks, dropping into the water below.

Urban, an environmental ecologist and director of the Center of Biological Risk at the University of Connecticut, was conducting his experiments with colleagues at I-Minus Lake, in far northern Alaska. The lake is surrounded by permafrost that is now rapidly warming and melting, releasing its material to the unfrozen world around it. “All day and all night, you hear that melting of the ancient ice,” Urban says.

One morning he woke up to see the mesolithic mud that had melted the day before refrozen and was inspired to take this photo, which spans an area of about a couple of feet. The image, to him, captures a moment in time when “the Arctic is warming faster than anywhere else in the world,” he says. “We’re seeing the landscape change before our eyes.” Each warm season, the area is losing 20 to 30 feet of its permafrost: frozen soil, rocks, and ice that have been encased for 10,000 years.

Urban started traveling to this same field site more than a decade ago. “The Arctic is a really special place, built upon permafrost,” he says. “That’s what gives it its special properties, that’s why it looks the way it does and has this beautiful, stark landscape.”

With a scientist’s eye, he notes of climate change that, “we’re seeing it in the biology of species, we’re seeing it in the changes in weather patterns, we’re seeing it in the patterns of flow in the rivers. But to see the land just disintegrate—almost before your eyes—I think is one of those images that really strikes you and says, *yes, this is really happening. And it’s happening quickly.*”

But the image doesn’t relay the sounds. During fieldwork there, he says, “every once in a while, you’ll pause and hear that noise.” *Plink. Plonk. Plink.* “And you think, *oh, what is that? Oh, it’s the melting of the permafrost.*” *Plonk.* “It’s a somber soundtrack for watching the world fall apart.”

—Katherine Harmon Courage

Photo by Mark C. Urban







We Can Be Heroes

*The transformative power of seeing your life as a hero's journey.
A reporter's eyewitness account*

BY ADAM PIORE

IN 1939, AT THE AGE OF 27, Sid Kline set sail for Europe, landing in Prague as the Nazis were on the march. The night before their arrival, he stood on a balcony with Czech aristocrats and helped them polish off their best champagne, then smashed the crystal glasses in the courtyard below so nothing would be left for the Nazis.

In the days that followed, Sid, the short-statured son of a Jewish shoe salesman from Camden, New Jersey, visited Berlin, rubbing shoulders with currency smugglers, mercenaries, and his fellow American correspondents. He traveled by train through treacherous border crossings, and smuggled a subversive manuscript penned by a Count into free territory. He returned home to Manhattan to settle down, married my grandmother, and soon after, my mother arrived.

ILLUSTRATIONS BY JOHN HENDRIX



By the time I came along, Sid had lost most of his hair, developed a healthy paunch and a hearty smoker's laugh, and taken a job as a rewrite man for the *New York Daily News*, where he wore a rumpled shirt and a green eyeshade, chain-smoked cigars, and spun reports coming in from the far reaches of the world's greatest city into narrative gold.

Sid used to tell me he couldn't imagine a more satisfying life than the one journalism had provided him—the stories he heard, the people he met, the adventures it afforded him. It was a life story that allowed Sid to live out his final years believing himself to be a blessed and grateful man.

I thought of Sid earlier this year when I read the psychology paper, "Seeing Your Life Story as a Hero's Journey Increases Meaning in Life." The title struck something inside me I knew to be true. It began with Sid, whose hero's journey increased meaning in my life—certainly more than the one offered by my other grandfather, a scientist who died far richer and with more renown but lacked Sid's talent for storytelling. But it's something I've also seen in countless others over the course of a long career traveling far and wide and speaking with people from all walks of life.

Sid's stories led me to become a journalist. They're the reason, when I reached my mid 20s, I quit a safe, secure job covering the New Jersey congressional delegation for a regional newspaper in Washington D.C., ignoring the warnings of my older colleagues who suggested my career would never recover. I felt stifled by the background politicking, calculations, and grandiosity of those in official Washington, a bubble where even the most extreme problems and high-stakes stories were somehow made to seem bloodless, bureaucratic, and disembodied from real human drama.

So, at 27, I moved to Cambodia, a raw, traumatized nation still emerging from 30 years of civil war, where everyday life seemed to be a matter of life and death. I wanted to meet and write about people who didn't have the option of a safe, predictable life. I wanted to be surprised. I couldn't ignore the ghost of Sid Kline—I wanted to have adventures.

And I have. I've pursued stories about people who, through the whims of fate, their own choices, or a combination of both, have found themselves in extreme situations that most of us can hardly imagine. Often the stories that are the most dramatic take a psychological toll on those involved. And often they've led me back to a series of questions that have long preoccupied me. How do people find meaning in the face of unimaginable tragedy, trauma, or disappointment? Why do some self-destruct, lose touch with reality, or give up, while others survive, recover, and find ways to draw strength from the challenges they were forced to endure?

Again and again, I found the answers zeroed in on the stories people told about themselves. During my interviews with genocide survivors in Cambodia, Vietnam veterans tormented by visions of their friends being obliterated in battle, victims of terrible accidents, survivors of workplace shootings, gang members in California's most notorious prison, I saw up close how important the hero-journey narrative, or something close it, was to them, transforming and even helping to save their lives.



“SEEING YOUR LIFE STORY as a Hero’s Journey” is written by Kurt Gray, a social psychology professor at the University of North Carolina at Chapel Hill, and Benjamin Rogers, an assistant professor in the Management and Organization Department at Boston College’s Carroll School of Management, along with eight colleagues in psychology. The authors were originally inspired by a screenwriting book, *Into the Woods: How Stories Work and Why We Tell Them*. *Into the Woods* author John Yorke writes that what makes a good movie is not necessarily the elements of the plot itself. What matters most is the growth and evolution of the characters at the center of that plot.

Gray chanced upon the book while going through a period in his own life when he felt purposeless and depressed. Nothing he could imagine doing seemed sufficiently epic. Perhaps, he thought, what was true about stories in movies and books that moved us was also true for our life stories. Maybe the problem was not that his life lacked meaning. Maybe the story Gray was telling himself about his life just needed a rewrite. “As human beings, we all grapple with meaning,” Gray told me. “Maybe my life could be more meaningful or less meaningful depending on how I think about it. We have this mind built for storytelling. We understand the world in terms of stories. And if that’s true, what stories are the best?”

In the paper, Gray, Rogers, and their colleagues unveil a “re-storying” intervention designed to help people transform the way they view their life stories—an intervention the paper suggests that can increase both meaning and resiliency in the face of life’s challenges. The authors designed their intervention by drawing from the “hero’s journey,” a classic story arc first identified in the 1940s by Joseph Campbell, the late scholar of comparative religion.

WARRIOR When he was in prison, Manuel Ruiz was determined to change his narrative, to become a hero of his own story. He began to think of himself as a “spartan,” a “warrior,” a man of substance and dignity.

KATE NICHOLSON





Anyone can have a hero's journey if you think about your life in a new way.

Campbell, influenced by the ideas of the spiritual psychoanalyst and Freud disciple Carl Jung, argued that universal elements could be found in the most enduring myths and fairytales of disparate, unconnected cultures across the globe since the beginning of recorded history. This suggested to him that human beings are wired to make sense of the world around them by placing them in the context of this innately satisfying narrative structure, which Campbell detailed in his seminal 1949 book *The Hero with a Thousand Faces*.

Stories as diverse as the *Odyssey*, *Ramayana*, King Arthur, and even the Bible, Campbell argued, each contained a series of recognizable stages that began with a “call to adventure,” and led to a transformative quest. Along the way, the protagonist received help from mentors, encountered allies and enemies, and overcame a series of trials before achieving success and returning home transformed. Famously, George Lucas has said he based *Star Wars* on *The Hero with a Thousand Faces*.

Gray, Rogers, and their coauthors boiled down Campbell's 17 stages of the hero's journey to seven: protagonist, shift, quest, allies, challenge,

transformation, legacy. They created a psychological test for people to measure the presence of those elements in their lives. Those who saw their lives as an epic journey scored higher on tests designed to measure meaning in one's life and the psychological elements associated with it—satisfaction, a sense of well-being, and the extent to which they were “flourishing.”

“The hero's arc connects the events of your life together, not just into different episodes, but one coherent narrative—and meaning is ultimately about connection, connecting up to bigger things, connecting together,” Gray explained to me. “Not only does it connect it together to something bigger, but it connects it together into something that resonates with us and is as timeless as we see in the movies.”

Gray told me he managed to put his crisis of meaning behind him. Though he recognizes that having kids is not saving the world, and “sitting by the playground is not as exciting as running from the black riders from *Lord of the Rings*,” he said he is determined to take new challenges in his professional life and make new allies in his personal one. “The point is,” he said, “anyone can have a hero's journey if you think about your life in a new way.”

ONE OF GRAY'S HEROES, and a coauthor of the Hero's Journey paper, is Dan McAdams, a professor of psychology at Northwestern University. In the field known as “narrative psychology,” McAdams is a Jedi Master—a pioneering theorist who drew together intellectual strands from multiple fields to help invent a new one in the 1980s.

A trim, bespectacled psychologist with a square jaw, and thick, gray hair that he wears swept back over a broad forehead, McAdams told me his ideas about narrative psychology grew out of his experiences as an assistant professor at Loyola University, introducing undergraduates to the work of Erik Erikson, the 20th-century psychoanalyst best known for his theories of psychosocial development.

Erikson suggested human personality development proceeded in a series of predictable stages, each one characterized by a key challenge; young adults like his students, Erikson maintained, and McAdams taught, were primarily concerned with the crucial task of forming a coherent identity. (Erikson is credited with creating the phrase “identity crisis,” and a failure to complete this phase of development results in “role confusion.”) Among McAdams' influences was French philosopher Paul Ricoeur, who argued humans came to understand their own identities by using language to draw together disparate events and establish causal and meaningful connections between them.

That conclusion has powerful implications, McAdams said. Psychologists have long argued that identity provides the compass that, as we grow older, we use to guide our journey through the world and understand our place in it. Our identity determines which groups we seek out when we feel threatened or anxious, it determines which ideas we will defend, fight for—even die for. It also molds our expectations, and directly influences our choices and actions.



For McAdams, an intellectual breakthrough came when he began to realize that stories weren't just a means to help form identity—story and identity were the same thing.

"If you could see an identity, it would be a story," McAdams said. "People have stories in their heads about how they came to be and where their lives are going. A story does all those things that Erikson said that identity should do. It puts your life together, past, present, imagined, future, beginning, middle, end. It links things together over time. It integrates different parts of yourself."

Each one of us, McAdams said, is wired to behave like an "autobiographical author"—to make sense of the world by creating stories about our lives. These stories "sit in our heads and they give our life a sense of purpose and meaning."

Some view their lives as tragedies. Others, comedies, or love stories. Some stories are as labyrinthine as a Dostoevsky novel, others as simple as Hemingway's *The Old Man and the Sea*. The way that people organize the events of their lives can reveal their level of resilience and influence the way they deal with adversity.

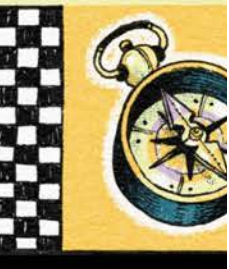
It's a theory that is now supported by a weighty body of research. McAdams has spent decades sitting with strangers, collecting their stories, then teasing out patterns and correlating those patterns with standard measures of personality, well-being, and other variables.

McAdams today is best known for his work studying the stories of adults between the ages of 40 and 65, a period of life where the tumult and uncertainty of youth has dissipated, and healthy individuals—at least the way Erikson saw it—are often focused outward, raising children, enmeshed in careers, and being active in society. The healthiest adults, Erikson suggested, had mastered what he called "generativity," they had developed a propensity to engage in acts that contribute to the greater well-being, and often promote the well-being of younger generations.

Indeed, McAdams found that, in middle-aged adults, just as Erikson theorized, there was a strong association between a deep sense of meaning, connection, and psychological well-being and generativity. The stories those generative people told, McAdams discovered, often shared common elements—elements prominent in the hero's journey—about overcoming suffering, triumphing over adversity, or being delivered from pain and persecution and turning challenges and setbacks into something positive.

"Highly generative adults love to tell you about their lives, almost as if they take pride in bad things happening," McAdams said. "They love to tell you about how they turned the bad stuff into good stuff."

McAdams also found common themes in the stories of those on the opposite end of the spectrum at middle-aged—those who instead of mastering the challenge of generativity had fallen into despair. Many of them believed that their most important life experiences were guided by fate, luck, and other circumstances beyond their control. McAdams coined the term "contamination" to describe a story element often seen in stories associated with the most miserable.





A NEW FRAME Dennis Charney, the dean of the Icahn School of Medicine at Mount Sinai in New York, was shot at close range by a former employee in 2016. Early in his convalescence, he said, “You realize that you can’t undo what happened, but you can reframe it.”

“Contamination means you have really great scenes that go suddenly bad and you can’t undo them,” he said. “If you have a bunch of them, or if you tend to see life that way, it’s trouble. Even if you have a positive event, you’re expecting the other shoe to drop. You’re expecting contamination. It becomes a self-fulfilling prophecy.”

I asked McAdams whether his findings, based for the most part on white populations in colleges and universities, applied to non-white, non-educated, non-American populations. He acknowledged that early in his career, he shared my concerns, and wondered whether his samples had skewed his findings.

But, he said, “we have never found any kind of relationship between education, income, and the ability to tell narrative stories about your life. Granted, we are not studying people who are homeless on the street, but we have looked at a broad range, from working class to upper class. The dimensions we look for—redemption, agency, communion, coherence—are not related to demographic variables. They’re not related to race either. We’ve done a lot of work with African Americans and contrasted them to Euro-Americans, and you don’t see big differences. Storytelling is basic. People respect stories and tell stories in all cultures.”

WHEN I ARRIVED as a new reporter in Cambodia, the country was still grappling with the legacy of three decades of civil war. Within a few days, I



Each one of us is wired to behave like an autobiographical author—to make sense of the world through our stories.

found myself interviewing—and working alongside—survivors of genocide. Most of the people I met had lost members of their family under the Pol Pot regime, a cataclysmic four-year period between 1975 and 1979 during which one in four Cambodians died of murder, starvation, or disease. Others had served as child soldiers, ended up in refugee camps, and suffered other traumas as the nation endured, not just a genocide, but a decade of a Vietnamese occupation, and a protracted low intensity civil war that kept Cambodia in poverty and crisis.

I saw things that left me shaken. I met an elderly woman begging on the street, who burst into tears when I asked her if she supported a United Nations tribunal to try former members of the Pol Pot regime, even though some were warning it could shatter the fragile peace. As tears streamed down her deeply lined cheeks, she described how Khmer Rouge soldiers had murdered her children in front of her by throwing them down the stairs. “They killed my children and that is why I am like this,” she said. Decades later, she still yearned for vengeance. The chance for justice was worth any cost.

But I also saw things that left me inspired. One day, I traveled up to the Thai border to visit a recently liberated former Khmer Rouge stronghold deep in the Cambodian jungle. For 30 years, music had been banned and the villagers had been forced to dress only in gray and black. I arrived to

find them clad in gaudy shades of pink, purple, and yellow—a joyous explosion of clashing colors, so jarringly mismatched it would have given Tim Gunn a heart attack. Later, sitting on a simple platform made of wooden slats, I listened as a woman told me about the day, just a few weeks earlier, when an enterprising countryman brought the first karaoke machine to town. Nobody had any money to pay for a song. But people came from miles around just to see it. And when that first maudlin Thai video flashed on the screen, depicting two young lovers by a riverbank crooning to one another in the melodic phrases of a contemporary pop song, the entire village burst into tears moved by the beauty of the simple cinematic and musical experience.

It was in Cambodia that I first became fascinated by the phenomenon of psychological resilience. That led me to the classic book, *Man's Search for Meaning*, by the Austrian psychiatrist and Nazi death camp survivor Viktor Frankl, a book that, long before the hero's journey paper came out, presented a “re-storying intervention” that convinced me and a lot of others too, that when people change the way they view their story, it can change the way they live their lives. Both Gray and McAdams told me Frankl's book had a profound influence on them.

At Auschwitz, Frankl observed his own physical and spiritual decline with grim professional detachment. He was called upon to counsel his fellow prisoners who had been pushed past the limits of their physical, psychological, and spiritual endurance. Frankl faced an impossible challenge. What is there to say, Frankl writes, to someone trapped in a real-life nightmare who insists, “I have nothing to expect from life anymore”?

Frankl's approach was to convince those in despair they could still be a hero in their own story. The death camps show that “everything can be taken from a man but one thing: the last of the human freedoms—to choose one's attitude in any given set of circumstances, to choose one's own way.”

“The way in which a man accepts his fate and all the sufferings it entails, the way in which he takes up his cross, gives him ample opportunity—even under the most difficult circumstances—to add deeper meaning to his life. It may remain brave, dignified, and unselfish,” Frankl wrote. The impact of this shift in thinking, Frankl argued for the rest of his life, could transform lives. Like the life of Manuel Ruiz.

I MET RUIZ IN SAN FRANCISCO in 2018, while researching a story on Inside Circle, a national organization that helps men inside and outside of prison rediscover their humanity, heal, and find purpose by offering group therapy seminars. During the gang hysteria that gripped Los Angeles in the early 1990s, Ruiz was convicted of shooting a rival gang member (who survived) and sentenced to life in prison. He arrived at California's Folsom Prison as a confused 19-year-old kid with no education, full of self-loathing, hopeless, “lost,” violent, and defiant.

Within three months of arriving at Folsom, Ruiz was sitting in the day room watching TV, when older members of the Mexican-American prison gang with which he was associated approached and asked him if he'd be willing “to put in





some work” for them in the prison yard. The Mexican Americans were at war with the Black inmates, and while the gang leadership had been serving time in solitary for fighting, five Mexican-American inmates in non-leadership roles had negotiated a truce with the Black inmates without their authorization. The older members wanted Ruiz to “send a signal.” They told him to carry out a nonfatal stabbing of one of the Mexican-American inmates who’d violated protocol. A couple days later, they sent him out into the prison yard with a knife made of sharpened metal taken from a clipboard, clenched between his butt cheeks. They also gave him an “ass-pack” consisting of a latex glove stuffed with tobacco, drugs, and messages to insert like a suppository in the expectation he would get sent to solitary confinement, “the hole.” Ruiz carried out his duty. He stabbed an older Mexican-American boxing trainer in the neck.

Ruiz got 16 months in the hole for the stabbing and began a violent journey that would land him in Pelican Bay, the supermax prison whose inmates included Charles Manson and Sirhan Sirhan. It was there that Ruiz discovered Frankl’s book, sent to him by his mother, and was introduced to older inmates who encouraged him to better himself.

Ruiz began waking up at 4 a.m. in his cell, doing yoga and tai chi, and working out. He refrained from cursing, forcing himself to do 50 burpees every time he slipped. He started doing crossword puzzles to improve his vocabulary. He avoided drinking and doing drugs (widely available in prison). He began to read, to study, to improve himself physically, mentally, and spiritually. He made a life for himself within the walls of his prison. (During the COVID-19 epidemic, during lockdown, he gave me advice on how to get through it without sinking into a deep depression.)

Ruiz told me he was determined to change his narrative, to become a hero of his own story. He began to think of himself as a “spartan,” a “warrior,” a man of substance and dignity. “I was sitting with the acceptance that I’m going to die in prison,” he said. “I’m not going to be able to see my parents. My whole reality was, ‘This is it, this is my life. What do I do?’ I knew Frankl went to the concentration camp, lost his wife. And his ability to change his perspective in the midst of that shit was a freaking huge deal. It was a big influence on me.”

By the time Ruiz left prison more than 21 years later, the unexpected beneficiary of recent prison reforms, he had transformed into an educated, leading advocate for incarcerated and formerly incarcerated men. Today he is the chairman of the board of Inside Circle.

Dennis Charney was also influenced by *Man’s Search for Meaning*, though when he read it, he had little reason to suspect the lessons contained in the book would ever apply to him.

Charney, who today is the dean of the Icahn School of Medicine at Mount Sinai, is an expert on resilience. He spent more than 30 years studying victims of sexual and physical abuse, those with congenital diseases, survivors of earthquakes, and prisoners-of-war from Vietnam who’d been kept in solitary confinement for years.

On Aug. 16, 2016, a former employee lay in wait for Charney outside his favorite delicatessen in his hometown of Chappaqua, New York. When

“They killed my children and that is why I am like this.”

Charney emerged with his morning bagel and cup of coffee, the employee, a disgraced scientist fired by Charney for scientific misconduct, opened fire at close range with a 20-gauge shotgun. The shotgun blast tore apart Charney’s right shoulder, punctured a lung, peppered his liver with buck-shot pellets, and caused him to lose half his blood.

After six days in intensive care, Charney returned home, so spooked he slept with the light on. He endured waves of irrational anxiety and fear, and fought off the instinct to hate his attacker, recognizing it as “negative energy that drags you down.” Early in his convalescence, he said, he recognized the opportunity to implement the lessons learned over his years of research. “You look at what happened to you, and you realize that you can’t undo what happened, but you can reframe it,” Charney said. “You can assimilate it into who you are as a person and move forward.”

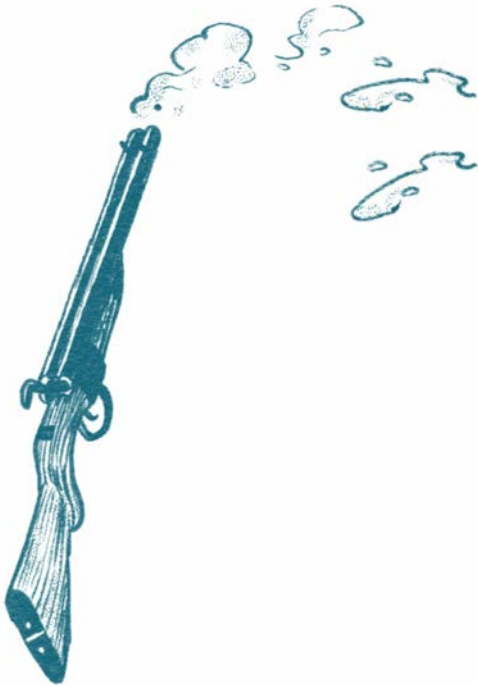
Charney’s road to recovery, just like the transformation of Ruiz, seemed to follow the steps of the hero’s journey. Charney cast himself as a protagonist on a quest to assimilate the shooting into his own story. He told me he had lost a grandchild to a genetic disorder. “Those things become part of your life story,” Charney said. “The great things, the loves of your life, and the traumas, come together in your life story. How you handle them contributes to your personal growth. The term we use in my field is ‘post-traumatic growth’—you grow from the trauma and that makes you prepared to handle other challenges in your life.”

Following the shooting, Charney identified obstacles and challenged himself. A competitive kayaker and weightlifter, he resolved to recover sufficiently to enter a kayak race by the following spring and compete with med students in an annual “strongest person competition.” He relied on allies—family, friends, doctors, and students for physical and emotional support. He embraced a legacy, seeking out other victims, sharing his wisdom and offering support.

“My recovery was very public because I’m the dean, and I was in the ICU of my own hospital,” Charney said. “And what I did for myself was realize I could be a real role model for other people because so many people were



When Charney emerged from the deli, the disgraced scientist opened fire with a 20-gauge shotgun.



watching my recovery.” Charney coauthored the 2012 book *Resilience: The Science of Mastering Life’s Greatest Challenges*, with Steven Southwick, also an expert on human traumatization. Southwick died of prostate cancer while writing the third edition. Southwick’s battle against cancer, Charney said, “ended up becoming part of his life story, his narrative. He fought heroically for five years.”

“WE TELL OURSELVES STORIES in order to live,” Joan Didion famously wrote in 1979. “We live entirely, especially if we are writers, by the imposition of a narrative line upon disparate images, by the ‘ideas’ with which we have learned to freeze the shifting phantasmagoria which is our actual experience.”

Didion’s loss of faith in “narrative’s intelligibility” is a pronounced theme today. “We’re told that story will set us free. But what if a narrative frame is also a cage?” asked *The New Yorker* in a 2023 essay, “Tyranny of the Tale.” Kieran Setiya, a professor of philosophy at the Massachusetts Institute of Technology, takes up the reasoning that imposing a narrative line on our lives reduces them in his 2022 book, *Life Is Hard: How Philosophy Can Help Us Find a Way*. “When you define your life by way of a single enterprise, a narrative arc, its outcome will come to define you,” Setiya writes. “It’s a tendency we should fight.”

I was curious what Setiya might think of the hero’s journey paper. When I described it to him in an interview, he had quick rebuttals. “If you’re thinking of your life in

narrative terms, you risk setting yourself up for a kind of life-defining failure,” he said. “You can narrow your perspective on life. You might think that making sense of your life in terms of a story can be meaningful and valuable and help you come to terms with difficult experiences. But that doesn’t have to take the form of a linear narrative of the kind the hero’s journey suggests. Lots of people have good lives without telling that kind of hero narrative.”

What’s more, Setiya said, “There’s the idea that if you can adopt the right attitude toward whatever circumstance you find yourself in, giving up on what’s out of your control, focusing on what’s in your control, and directing your agency at that, you’re guaranteed to achieve a flourishing or meaningful life. I don’t think that’s true. I don’t think there’s any guarantee, unfortunately, that people’s lives are guaranteed to have the potential to be good and meaningful.” Telling people they can overcome terrible situations, he added, “is a kind of deception that is uncharitable and unempathetic to people. It’s a failure to acknowledge that there are circumstances under which people’s lives are terrible in ways that no change of attitude could possibly compensate for.”

It was hard for me to disagree with Setiya’s last point. It would be absurd to suggest the Cambodian woman who told me about the death of her children might somehow recover from the trauma by reinterpreting the events of her life.

It wasn’t hard for McAdams to disagree with Setiya. “Decades of research and clinical experience show that changing beliefs, stories, and self-understandings do indeed change lives,” McAdams said. “People can become happier by changing their thoughts about life. I mean, this is so fundamentally true that I don’t believe I have to argue it.” That said, he added, “happiness and meaning are not solely the product of beliefs. The real world counts. In fact, one of the great values of life narratives is that they change over time. People change their narrative self-understandings as life evolves. Narratives are not fixed traits. They are dynamic and elastic cognitive structures, showing remarkable flexibility in their integrative power.”

As a journalist, I’ve chosen a life that venerates narratives. They are a central part of the story I tell about myself. And when I think about the inspiring people I’ve met, the transformative power of the hero’s journey rings true. The most important factor setting apart those who recover from life’s trials from those who succumb is the ability to maintain a sense of agency, “to choose one’s attitude in any given set of circumstances, to choose one’s own way,” Frankl wrote. Far from caging us, the stories we tell about ourselves can set us free. ☺

ADAM PIORE, a veteran journalist, is the author of two books and a longtime *Nautilus* contributor. He currently covers health and infectious disease for the *Boston Globe*.





A photograph of two fishermen in a small boat on the water at sunset. One fisherman is standing and holding a long pole, while the other is sitting. The sun is low on the horizon, creating a warm orange and yellow glow. The sky is a mix of orange, pink, and blue. The water reflects the colors of the sky and the silhouettes of the fishermen.

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Why Is Everything an Orchid?

Orchids were Darwin's "abominable mystery." They continue to elude science—and efforts to save them.

BY SOFIA QUAGLIA

A**FTER INVESTIGATING THE ORIGIN** of the species, Charles Darwin lunged into an exploration of something that seemed, by comparison, terribly minute: orchids. By 1862, he'd traveled the world wide and far, encountering incredible organisms like giant tortoises, seafaring iguanas, and fossils of giant ground sloths. But he couldn't stop thinking about a delicate, white, star-shaped flower he'd been sent as a gift by his acquaintance James Bateman, an English horticulturalist with a penchant for rare flora from Madagascar. The flower's odd shape—with an extremely long nectar pouch hanging under its crown—stirred in him a deep, almost inexplicable fascination.



“Orchids have interested me as much as almost anything in my life,” Darwin wrote. In their forms, he saw a vast landscape of the forces of selective evolution, a dance they played with their environment and their pollinators. “My little darlings,” as he sometimes referred to orchids, became his model for further exploring the forces he so broadly described in *The Origin of Species*. Just three years after the publication of that shattering work, he had produced his tome puzzling over the multitudinous, striking habits of orchids: *On the Various Contrivances by Which British and Foreign Orchids Are Fertilised by Insects*, and *On the Good Effects of Intercrossing*.

How a single family of flowers could vary so widely—from small and frilly, almost invisible to see, to large, gaudy and with a front pouch—left Darwin baffled. He called this, and flower diversity as a whole, an “abominable mystery.” Indeed, there are upward of 28,000 species of orchids worldwide and new ones cropping up every so often—sometimes even right under our noses. They have made their homes on all contemporary continents save for Antarctica—from the Arctic north, across the equator, and reaching south through all but the tip of South America.

“I think the reason people become obsessed with them is because of that mystery: Why are there so many?” says Jamie Thompson, a life sciences researcher at the University of Bath, in the United Kingdom. Yet

the scientific jury is still out—and fervently debating—how many species there are exactly, what secret makes them so brilliant at diversifying, and when and where orchids evolved in the first place. Getting to the bottom of these mysteries could help us better understand the evolutionary dynamism of this massive group of alluring plants, and how we might help them fend off upcoming decimation.

To search for answers, researchers have spent decades digging into the orchid’s past. For plants, fossil records are often hard to come by because soft organic matter is less likely to be preserved than, say, bones. To track when a plant first appeared on this planet, experts now tend to rely on phylogenetic profiling: They use DNA from different species to plot them onto a tree of life, and then use a statistical model to pull them back into the past and recreate their history.

When, in 2015, researchers used this technique to sequence 39 species from all major orchid groups, as well as data from some fossils, their findings suggested that orchids originated between 102 and 120 million years ago, most likely in Australia.¹ Ancient orchids then spread to the tropics by making their way through Antarctica—which was then connected and flourishing with vegetation. And since then, Southeast Asia is where most of their speciation has taken place.



ORCHIDS EVERYWHERE

There are some 165 species of lady slipper orchids alone, a subfamily found on four continents. Nevertheless, some lady slipper orchids usually die when removed from their natural habitat.

This paper, posted to a pre-print site in late 2023, hasn't yet been peer-reviewed, and some outside experts don't think this new hypothesis is any good. But Oscar Pérez-Escobar, the lead author of the study and a researcher at the Royal Botanic Gardens, Kew in the United Kingdom, doesn't think his findings are controversial at all. "Understanding where things come from can help us understand why we have X or Y species, and why there are so many," Pérez-Escobar says.

Today, it takes a long logbook to account for orchids' present diversity of appearances and habits. "There's quite a number of innovations that orchids can do that other plants can't, or not so well," says Katharina Nargar, an orchid researcher at James Cook University, in Australia who contributed to the new study.

Or at least, this is currently the leading theory about orchid origins. It may soon be upended, though, according to new preliminary findings.² An international team of researchers has drafted a study using DNA from more than 1,900 species of orchids and pinpointed their origin north, in Laurasia, modern-day Europe, Asia, and North America. The majority of diversification happened just over the past 5 million years, their work suggests, and southern Mesoamerica, such as the lush Costa Rica and Panama, actually hosts the fastest speciation of orchids.

The neatest and most helpful of these tricks, according to Nargar, is that more than 70 percent of orchids have developed the ability to grow out of tree trunks and branches instead of soil—a capability known as epiphytism. This allows them to exploit new territories other plants cannot use, giving them “free rein,” says Nargar. Studies suggest that epiphytism evolved independently at least 14 times throughout the orchid family tree, and epiphytic orchids are “significantly richer in species” than terrestrial ones, write the authors of one study of their diversity.³ To successfully live in



BEE-LIEVABLE This orchid, *Ophrys apifera*, looks and smells like a female bee, tricking male bees to spend more time with them, and become unwitting pollinators.

trees, orchids have developed the ability to absorb moisture from the air via a succulent spongy outer coating on their stem and leaves, as well as to use their roots directly to photosynthesize. The *Taeniophyllum* orchid, for instance, doesn't even have any leaves: it just uses its roots for all energy production from the sun.

For the species that haven't evolved to live in trees, the other main running theory for their inexplicable ability to diversify lies in how specialized their flowers are at getting pollinated. For one, some orchid species are the ultimate swingers—they're very lenient in their sex lives and can produce fertile offspring with orchids

from some other species, making them more likely to reproduce and more likely to often birth unique, new hybrid species, according to Nargar.

To ensure pollination, some orchids also strike up an evolutionary deal with local fauna: The plant evolves a flower so intricate it's only accessible to a few types of insects, and those insects are sure to only really ever pollinate other orchids. One of these striking examples is the *Angraecum sesquipedale*, the orchid Darwin had grown obsessed with, which has evolved a 12-inch long and narrow satchel for its nectar so that only the hawk moth, with an exceptionally long proboscis, can access



LEAF ME ALONE This orchid, *Taeniophyllum glandulosum*, never grows leaves. Instead, it has chloroplast-containing cortical cells in its roots, with which it meets all its photosynthetic needs. Its roots are not buried in soil, but rather wrap around a tree trunk or rock.

it. Although Darwin had already mused on this possibility, the moth hadn't yet been discovered, so his theory was only confirmed almost four decades later, in 1903.

In order to fine-tune their ability to accommodate just certain pollinators, orchids have also grown very meticulous about how they deliver their pollen gifts. Some orchids bundle their pollen in tailor-made, measured, sticky packages and fling them onto their preferred pollinators with precision so that no grains are wasted and lost along the way once they fly off, and they can only be dislodged once they reach their destination. This push to specialize pollen packaging according to available pollinators—maybe a moth, maybe a

bee—has also pushed diversification. And it allows one mutant orchid to have a higher chance of having loads of offspring because less pollen goes to waste than with traditionally dispersed grains. The branch of the orchid family tree that has evolved this trick called “pollinia” has a higher speciation rate than orchids that have stuck with traditional pollen grains.⁴

To take their specialization a step further, some orchids have evolved to mimic the mate of their preferred pollinator, or their favorite snack through looks, scent, and the release of special chemicals.⁵ Unknowing insects show up on their flower crown hoping to get lucky, and get duped into picking up the flower's pollen

instead. *Ophrys apifera* orchids look and smell like female bees. The Hammer orchid eerily resembles a female wasp. The *Satyrion pumilum* orchid, in South Africa, imitates the scent of dead animals to attract fruit flies, while *Disa pulchra* orchids pretend to be other nectar-offering flowers, like the pink iris, to fool insects into coming looking for a sweet reward. Since bees, wasps, and butterflies alike would clock the ploy if it were too common, it's possible this has led orchids to vary in their mimetics as much as possible, spurring the birth of so many different species and tactics.

These unique flower morphology strategies are “fundamental,” to diversification according to Dewi Pramanik, an orchid morphology researcher at the Naturalis Biodiversity Center, in the Netherlands. One of her favorites is the *Serapias cordigera* orchid, which has evolved to shape its hairy, burgundy flower like a comfortable resting place for the *Hoplitis adunca* male bee, which will conveniently stop to rest there in between bouts of foraging, accidentally pollinating the flower.

Dust-like seeds are also likely among the orchid's arsenal for rapid diversification. A single orchid seed packet can contain up to 4 million seeds, sometimes as tiny as 0.05 mm in length—the smallest in the plant kingdom—meaning plenty can easily disperse with a single gust of wind. Although most of the dust seeds won't ever germinate, this tiny seed technique does increase the odds for diversification compared to a plant with a heartier seed bulk because new plants can crop up quickly in new locations without too much energy expenditure, and rapidly adapt accordingly.

Though orchid excellence might not all be down to just tricks pulled by the plants themselves, according to Thompson—there are external factors at play, too. When Thompson ran another phylogenetic statistical analysis on nearly 1,500 species of terrestrial orchids, his data suggested that their diversification “exploded” specifically when temperatures started dropping across the globe, somewhere around 10 million years ago.⁶ Global cooling is 700 times more likely to have influenced the rate at which orchids speciated than just time alone, Thompson says, making orchids “the best example of climate-driven speciation.”

Unfortunately, this also suggests extra trouble for the challenges orchids will face as the world warms. “I think extinction will increase, because a lot of them are cold-adapted, and we've seen in Europe how hot it's been,” says Thompson. Climate changes also put orchids at additional risk due to their hyper-specializing for one pollinator that might die off or be forced out of their habitat.

Going by their evolutionary history, orchids should continue to proliferate, and we should continue to discover new ones. “If you look at the number of orchid species described against time, it's not really showing any evidence of leveling off,” according to Thomas Givnish, a professor of botany and environmental studies at the University of Wisconsin-Madison, who penned that seminal Australia-orchid-origin research. But human-caused climate change and other habitat destruction are spelling out a different future for many of these species of flower.

How a single family of flowers could vary so widely left Darwin baffled.

*Darwin couldn't
stop thinking about
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star-shaped flower.*



STARSTRUCK The *Angraecum sesquipedale* orchid—the very same type Darwin had grown obsessed with—has evolved a 12-inch long and narrow satchel for its nectar so that only the hawk moth, with an exceptionally long proboscis, can access it.

Some orchids are very lenient in their sex lives.

Some calculations suggest that plant species are dying out at least 500 times faster than before 1900, with orchids high on the threat list. Bangladesh has lost 32 of its 188 identified orchid species since 1996; in the Czech Republic, the suitable habitat for endemic orchids has declined up to 92 percent; in Florida, the number of famed ghost orchid (the sought-after subject of *The Orchid Thief*) has declined by half; orchids in India are blooming earlier than they should, potentially disrupting pollination. And according to a study published earlier this year, almost 280 known orchid species are in need of “immediate conservation action” but most of these still lack adequate protection.

If most of the diversity arose in the past 10 to 5 million years, the rapid loss of species we’re experiencing now might be too late to counteract, according to Pérez-Escobar. “We are kind of stuck,” he says. “If we don’t protect the orchids that we have left, the time it will take for that orchid diversity to bounce back is millions of years.” He’s on a mission to gather additional international collaboration to sample the DNA of all existing orchid species—however many they may be—because he thinks that will help him definitively plot out the plant’s evolutionary history.

The one thing experts seem to all agree on is that perhaps the best way to come up with strategies to effectively stop orchids’ decline⁷—whether it’s going to be saving the habitats they reside in, focusing on the pollinators they rely on, cutting down on their illegal trade, or all of the above—is to somehow answer the big questions of the “abominable mystery”: What are the secrets to their success in speciation? Further parsing these details about orchid diversity can help conservationists hone in on their rapid and wild evolutionary plasticity to, hopefully, give them a fighting chance at adapting to a rapidly changing world.

After all, Darwin, himself noted that orchids had been “eminently useful” for him to learn how every

little element, “even most trifling details of structure,” are somehow a result of natural selection.⁸ As he wrote in a letter replete with exclamation points to a fellow botanist: “The beauty of the adaptations of parts seems to me unparalleled.” ☺

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The Happiest Man in the World

Harry's psychotic delusions bring him cheer. His psychiatrist embraces them.

BY PAGAN KENNEDY

SEVERAL YEARS AGO, a British man named Harry picked his nose. A hidden camera recorded him in this private moment, then someone uploaded the video to the internet, and soon Harry's pratfall exploded into a worldwide meme. Millions of people—most of them in the United States—became obsessed with the video. Everywhere Harry went, strangers shot significant looks at him and touched their nostrils, as if to say, “Hey, you’re that nose-picking guy!”

Harry loved the attention—he described his fame as a “safety blanket” and said he felt as if everyone on the street had become his friend. But there was a problem with Harry's internet stardom: No one else could perceive it.

In a parallel reality where most of us live, Harry had been diagnosed with psychotic delusions, many of them seemingly borrowed from the YouTube videos he obsessively watched.

His family convinced him to visit a mental health clinic affiliated with the University of Birmingham. There, he enthused to his clinician—Rosa Ritunnano—that he was “the happiest man in the world.” Harry told Ritunnano that he could read and control other people's thoughts; he deployed his telepathy to battle the lizard-humans and the Illuminati at the center of a web of power. These enemies, for their part, surveilled him through hidden cameras and telepathic spies.



As nightmarish as that all might sound, Harry relished the attention from the imaginary conspirators who monitored him. “If I found out that they [were] not watching me and reading my mind, I would feel alone and crazy,” he explained to Ritunnano.¹

Though he was engaged in an apocalyptic psi war, Harry was also a remarkably pleasant fellow who seemed to pose no threat to anyone. He did refuse his prescribed antipsychotic medications, but when Ritunnano and her colleagues asked him whether he would submit to a battery of pencil-and-paper tests, he cheerfully agreed. And so the doctors administered some whimsically named tools that are used to measure self-worth, including the Purpose in Life Test, the Life Regard Index, and the Existential Meaning Scale. Harry aced them all.

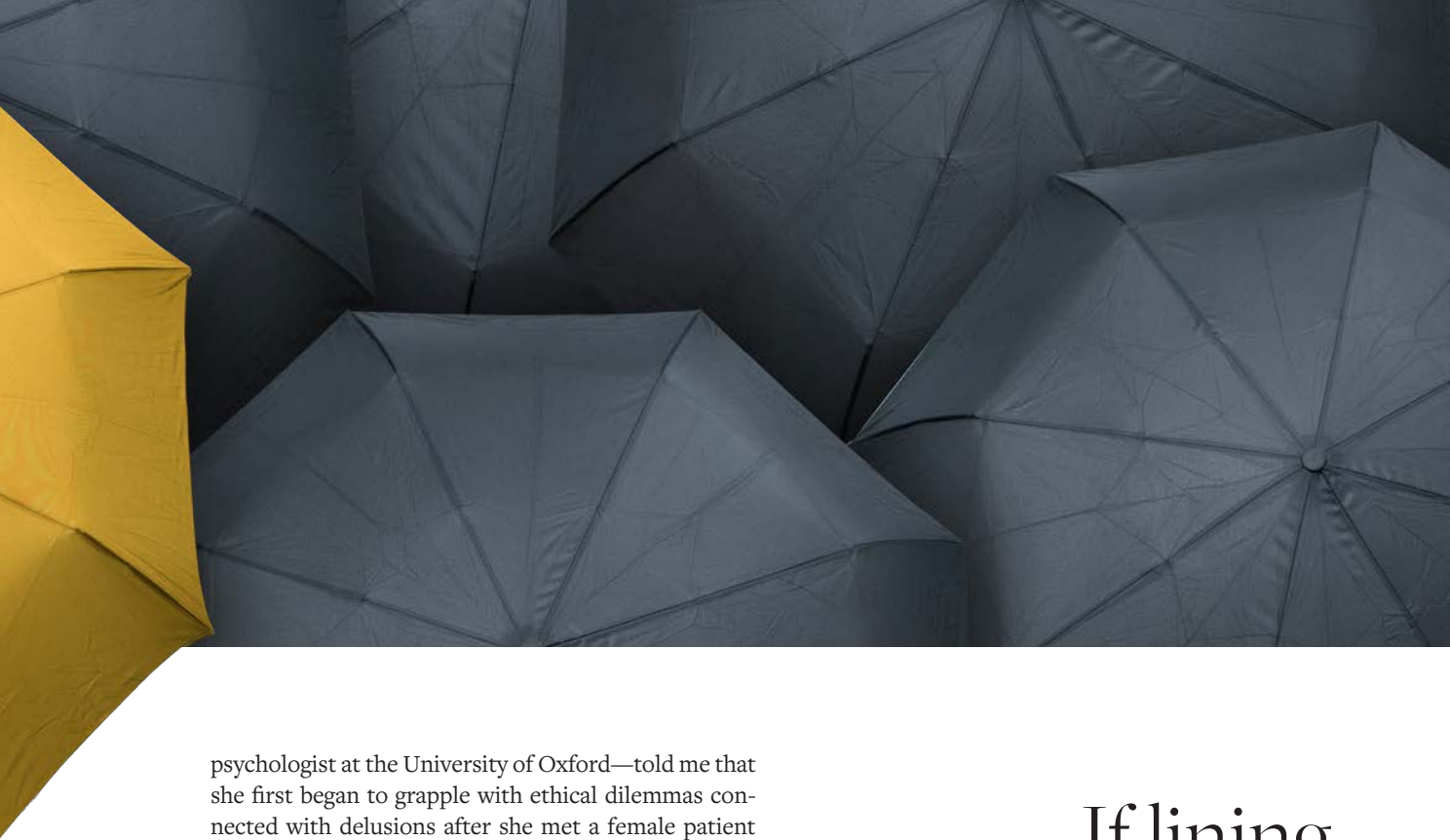
IN THE PAST DECADE, the Hearing Voices Movement, a federation of people who experience auditory hallucinations, has pushed the medical community to acknowledge that their symptoms can be a meaningful adaptation to trauma.² Ritunnano belongs to a compatible movement among caregivers—when she met Harry a few years ago, she had just

started her Ph.D. in a field known as phenomenological psychopathology, which puts the doctor’s sense of reality on an equal footing with the patient’s.

In Harry, Ritunnano saw a teacher. She thought she could “learn something about what it means to be happy” from him. At the same time, she struggled with her obligations as his clinician: How was she supposed to help a man like Harry?

Clearly, his psychosis had cost him some heartbreaking losses. Due to Harry’s odd behavior, and concerns that his children might be at risk, he was barred from seeing them for a period. Even when he was able to see his children more regularly, Harry often spent his days glued to YouTube, addicted to videos about the flat Earth and other conspiracies, making it impossible for him to work and damaging his family life. And yet he reveled in his imaginary superpowers, which he told Ritunnano connected him to all of humanity. Now, he said, all “people are like a family for me.”

Ritunnano isn’t the only one asking such questions. Louise Isham—a research clinical



psychologist at the University of Oxford—told me that she first began to grapple with ethical dilemmas connected with delusions after she met a female patient who believed she worked undercover as an MI5 spy. The patient’s “missions” let her imagine that she was rushing around the world to battle villains and gave her a sense that she was serving her country. So even if doctors could find a way to bring the patient back to reality, would that be the right thing to do?

This question inspired Isham to scour the psychiatric literature for guidelines on how to treat patients with “grandiose delusions.” (The term is psychology-speak for delusions involving fantastical powers or secret knowledge.) As it turned out, there were no clear guidelines. Isham realized, “this is an area that’s massively under-researched.” She told me, “there is a genuine problem that I’ve witnessed in clinical services, where you can see the harm that’s coming from a patient’s grandiose delusions, but there’s also a clear benefit to the belief, and there is a real lack of empirical literature that tells us what to do about that.”

Patients with “superpowers” might decide to fly off the top of a building or to baptize strangers—and often they may be so busy with their imaginary role that they lose their real-life jobs and become socially isolated. And yet, “given the benefits that people can get” from their delusions, Isham said, “you have to be really careful not to go in and make things worse.”

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Let’s do it.



They are
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In order to learn more about this condition, Isham and her colleagues identified patients with grandiose delusions and polled them about their experiences as messiahs, secret agents, and conspiracy-investigators. You might think people described as “grandiose” would dream themselves into the billionaire class and indulge selfish desires—if you have godlike superpowers then why not sail an imaginary yacht to Macau and win every hand of blackjack? But Isham and her coauthors found that most of the patients had created a fantasy world where they performed selfless acts, even miracles, to help others.³ About 70 percent of these patients reported that their “special powers” helped them to make other people happy and to protect others from harm.

Perhaps the inner life of these patients tells us something more universal about the search for meaning: For most of us, self-worth depends on being useful to others. And we, like Harry, are always struggling to find human connection—but he and others with psychosis might get that need met more easily by communicating telepathically with fictional strangers than in person with family or friends.

As Isham said, “This is a very misunderstood group of people.”

CAROLINE MAZEL-CARLTON WOULD AGREE with that. She told me that she heard her first disembodied voice after being abused by a daycare worker. The woman—who had hit young Caroline and scalded her with chemical cleaners—was chatting with another adult, and said, “It’s such a nice day. Not a cloud in the sky.”

That’s when the voice in young Caroline’s head spoke up: “She’s lying. I hate her.” Mazel-Carlton told me that the voice—she would later name it “Frank”—didn’t frighten her at first. If anything, he seemed to be coming



to her defense. But later, voices turned into a swarm of tormentors. As a teenager and young woman, Mazel-Carlton bounced from mental hospitals to jail cells, where doctors numbed her with pills.

In her late 20s, Mazel-Carlton detoxed from psych meds and learned how to tame and soothe even the most frightening voices in her head, including “Frank.” If Frank orders her to throw a chair across the room, for instance, she can “satisfy” him by simply touching the chair or turning it over.

Nowadays, Mazel-Carlton uses her lived experience to guide other people—she’s the director of training for the Wildflower Alliance in Western Massachusetts. A support network that’s aligned with the Hearing Voices Movement, the Wildflower Alliance brings together a community of peers to cope with voices, visions, and other “extreme states.”

Years ago, when Mazel-Carlton was on the other side of the consulting table, the doctors would ask her whether she was hearing voices, yes or no? And the conversation would usually end there—with a diagnosis and a prescription for meds. But now, as a caregiver, she explores her clients’ hallucinations with probing questions that her own doctors never bothered to ask: “Do you want to share what your voices say? How do they make you feel? Do your voices remind you of anyone you’ve known in the past?”

Mazel-Carlton said that “as mental health professionals, we’re not really doing our job if we’re not looking for meaning,” and she emphasized that caregivers

should recognize that psychosis can be a survival tool. As an example of that, she told me about a man she’d met in a locked psychiatric ward who announced that he was the president of the United States. The patient “had been through horrific institutional trauma. He was once stripped naked and handcuffed to a sink by police,” she said. And now the psychiatrists on the ward wanted to drug the “president” back into painful reality.

Mazel-Carlton had a different idea. She invited the patient to walk the halls of the locked ward with her, and then she asked him, “How does it feel to be the president of the United States?” She wondered if he regretted becoming the most powerful person in the world. Wasn’t he overwhelmed by his responsibilities?

He told her, no, he loved being president. “He shared with me that he was reflecting on who his cabinet members would be, and he asked me if I wanted to serve on the cabinet,” she said. “He wanted Beyoncé to serve in another position in the cabinet, and that gave him so much joy.” For Mazel-Carlton, the patient’s fantasy seemed an act of heroism—he’d recaptured his own human dignity and found a reason to keep on living.

Mazel-Carlton believes that the last thing you should do is to tell someone that their voices and visions aren’t real. “If I were to do that, I’d sever my connection with them,” she said. “If I don’t validate their own fears and concerns, why would they turn to me as a source of support?” And so, like an improv actor, she jumps into their stories with them. This allows her to help the patient change a potentially dangerous narrative to one that’s



Like an
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benign. “If the CIA is asking them to monitor their neighborhood and they’re ending up in people’s yards or looking in mailboxes, that’s when I ask them to imagine other ways to complete their mission. Like, could you get to know your neighbors?” And if Jesus or Allah feels the need to cut out their own eyes as a sacrifice, then Mazel-Carlton suggests other ways of performing the holy ritual. She might encourage the client to make a drawing of the sacrifice, or to say a prayer.

“Anything that gives someone the sense of power and won’t hurt them is great,” she says. “If lining a hat with tinfoil gives a person a sense of power, wonderful. Let’s do it. Buying a cell phone jammer for the room? Great. Let’s do it. Because when we can give a little bit of power, then we can often have the conversation about the deeper seed of truth and meaning.”

She acknowledges that her methods are out of sync with mainstream psychiatry. She and others in the Hearing Voices Movement are “throwing ourselves bodily at the Overton Window,” she said, meaning that they want to expand the spectrum of acceptable treatments for people who struggle with mental-health problems.

THIS SEEMINGLY RADICAL APPROACH has its critics. Ian Gold, a professor of philosophy and psychiatry at McGill University, told me that clinicians may need to make judgment calls on behalf of patients who are suffering. “There’s a spectrum of patients,” he pointed out. “Somebody might say, ‘I’m happy and I have this delusion.’ But really they’ve got an illness that is not severe.” He noted that if a patient is struggling with depression or feels tormented by their voices, then the clinician may need to treat the underlying pathology that causes their pain.

VERONICKA / SHUTTERSTOCK



Ritunnano made much the same point. She told me, “It’s not about the actual belief, it’s about the individual and their social context.” If a patient with severe bipolar disorder suddenly becomes terrified of black cats, that might be “a harbinger of serious decline, and they will need intense support to avoid hospital admission.” On the other hand, she said, when a patient with a long-time delusion that he’s being tormented by aliens suddenly stops talking about spaceships, that may be a sign that he has slid into depression and needs medication for that—rather than for his delusion.

Still, many clinicians are now embracing methods that empower patients to live with their voices and visions if they so choose, including a form of cognitive-behavioral therapy in which patients learn to cope with hallucinations. In one recent paper, for instance, researchers pointed out that clinical guidelines from countries around the world suggest that people with psychosis should have a say in their own therapy—even if that involves refusing to take medications.

And that brings us back to Ritunnano’s question: What can we learn from Harry’s happiness? She told me that working with Harry challenged her to think differently as a clinician. “With Harry, it was mostly about being able to sit with the uncertainty,” she said. “While our job as clinicians is often focused on treating ‘symptoms’ and managing risk, Harry’s case reminded me that we are also always confronted with the existential struggles that accompany health and illness alike.

What do you do when eliminating ‘illness’ also means eliminating meaningfulness?”

Harry had no complaints, and there were no immediate concerns about harm coming to him or others. So, as long as his joy lasted, Ritunnano’s job was to believe in it, rather than treating it as a symptom to be snuffed out. Harry had discovered that his best life could be in his fantasies. As he once told Ritunnano, “I feel like Jesus. Of course I’m not [Jesus.] But why not believe?” 🌀

PAGAN KENNEDY is the author of 11 books and is a former columnist for the *New York Times Magazine*. Her next book, *The Secret History of the Rape Kit*, will be published in 2024 by Pantheon.

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Thank Eve for Human Evolution

It's females who vaulted biological hurdles and forged our evolutionary success

BY LUCY COOKE

IN OCTOBER, AT THE CHELTENHAM LITERATURE FESTIVAL in England, Cat Bohannon was sporting a pink latex top and a mischievous twinkle in her eye. She and I shared a stage to talk about our recent books; in my case, *Bitch: On the Female of the Species*; in hers, *Eve: How The Female Body Drove 200 Million Years of Human Evolution*. We hit it off immediately.

Eve, Bohannon's first book, is a sweeping revision of human history that places the female body center stage, instead of just a feminine footnote to the macho main event. Bohannon, a Ph.D. from Columbia University (where she studied the evolution of narrative), with a sideline in poetry and performance, tells this epic tale through a series of "Eves"—presumed ancestors who vaulted various biological hurdles, with pivotal consequences for our evolutionary path.

Eve begins in the Jurassic period with a small rodent *Morganucodon*, nicknamed Morgie by the Smithsonian, which laid eggs and lacked nipples but nevertheless became the first mammalian breast feeder. We discover that milk is alarmingly like pus, but with added prebiotics for developing gut health. Next comes *Protungulatum donnae*, "our womb's great-grand-rat," who managed to survive the apocalypse that wiped out the dinosaurs by inventing the placental pregnancy.



By the time we get to our hominin ancestors, with their ever-expanding brains, this internal incubation system is starting to creak—mammalian mothers are at war with their fetuses over limited resources and hominin heads too big to pass through the pelvis. It is this fundamental biological limitation that shaped our trajectory far more than man the hunter, farmer, or toolmaker ever did. In Bohannon's myth-busting tale, reproductive choice and the need for midwifery drove the evolution of a matriarchal society, like the one we see in our great ape relative the bonobo.

Eve's structure reminded me of Richard Dawkins' *The Ancestor's Tale*, but the content, with its female focus, could not be more different. Bohannon shares Dawkins' gift for compelling science communication but has her own intimate style. The book took her 10 years to write. During this time, she finished her dissertation and became a mother. Twice. Alongside all the Eves, we meet various incarnations of Bohannon herself, from life-drawing model to almost sex worker (during college she interviewed for a job as an escort but decided against putting her "vagina up for rent"). Her personal stories bring grit, humor, and humility to those of her imagined Eves.

Not long after the festival, Bohannon and I spoke over Zoom about the incredible *Eve*. Talking to her is like being struck by a tornado of ideas.

Tell us how midwives set our ancestors on the evolutionary path to success.

Because this is for *Nautilus*, and it's a science credit, I'll start with a high-minded idea and dig in. Paleoanthropologists don't give a damn about rocks. That's not what they're actually studying. What they really want to know about is the triangulation of an object that is a tool, its user, and its environment. From that you can infer ideas about a creature, its cognitive capabilities, its likelihood of socially shared knowledge, its relationship with food-stuffs. There's a lot you can learn from rocks.

Tool use is fundamentally about doing something to overcome a basic limitation of your body plan in your environment. How does utilizing a tool get you there? What behaviors are you doing to overcome that limitation? Our biggest problem wasn't food. I mean, it's always food. We're always hungry. Our most important problem was we were crap at making babies.

By looking at fossils, we've determined that many in the hominin line share this problem—our pregnancies got longer and more difficult and more prone to crippling and sometimes deadly complications for the mother and child than they are for almost any other primate. In evolutionary biology, that's a hard problem. You can limp around on one foot, you can have a weird neck, you can be many things in the animal world. But if you suck at making babies, then you are not destined for great success. You're certainly not destined for massive migration plans that end up in every environment in the world.

Enter the midwife.

Right. If need is the mother of innovation, look at the mothers. The way they innovated is with behavior. Our workarounds are always behavioral. And midwifery is a behavior. But it's a behavior that requires major shifts in a social organization. You need to have strong female bonds where you can trust someone between your legs when you're giving birth.

Jane Goodall and many other wonderful primatologists have seen that there's a lot of female infanticide. When you're giving birth as a chimpanzee, you're going off secretly, then carefully reintroducing that newborn to the group, and only to your friends first. If you're not friends with the alpha female, you're avoiding the hell out of her because she's not just going to kill that kid, she's going to eat it in front of you, while you scream.

But it's not just about midwifery. Any good OB-GYN will tell you how your pregnancy, birth, and postpartum recovery are deeply dependent on your prenatal care. They're also deeply dependent on the whole history of your reproductive life and general health before you ever get pregnant. So, given your local environment, and what's going on around you, it may be healthier to have less children, or have them in a cluster, which is also a behavioral innovation. I'm not the first to say that Lucy [the name for an australopithecine skeleton from over 3 million years ago] had a midwife. She shared our obstetric dilemma.

The traditional model for hominin society has been based on chimpanzees—a patriarchal society where females disperse from their natal group and don't have strong bonds with one another. But your midwife

Talking to Cat Bohannon is like being struck by a tornado of ideas.

argument supports those that see our other great ape relative—the matriarchal bonobo, with her sisterhood of unrelated females—as a more convincing model. You even found evidence of bonobo females supporting one another giving birth, which I found incredible. The thing that I found most interesting about it wasn't simply the laboring female was so obviously trusting of the others. It was that they shared the placenta. We've wondered about how midwifery might take hold as a regular practice in a species—you need those strong female bonds. Usually, the argument is a mother is helping a daughter, or a sister—you must have that genetic bond. But now there is an immediate reward. I have never eaten a placenta—and have no desire—but that's a nutritive reward for being around. And the bonobos are passing it and sharing it. And sharing food in primates is a big social bonding thing. So, in other words, you get a meaty bloody treat for helping, and also not harming the child.

Speaking of blood, menstruation is a bit of an anomaly. Humans are part of an eclectic and unrelated assembly of bleeding female mammals that includes a handful of primates, four bats, the elephant shrew, and a spiny mouse. Why?

We like to focus on the blood and tissue and mucus coming out of the hatch. But that isn't the most

biologically interesting thing. It is probably just an accident of it being less expensive to just shed the stuff rather than reabsorb it. A lot of species just reabsorb it.

What's interesting about the way that we have a menstrual cycle is that we build up our endometrial lining without any signal from a fertilized egg. Most beasts only start doing that when they get that hormonal signal that a fertilized egg is incoming. Then you get rare creatures like us who have a very invasive placenta that penetrates all the way down into the mother's bloodstream. This is a partial allograft that's docking in—the basal plate of the placenta being of the mother's body, and then the top plate being made of fetal material from the embryo. The placenta is the only organ that's made of two different organisms.

So, it's like trench warfare, right? Because there's maternal fetal competition for resources. That means the mother's body has long evolved to survive and resist invasion. And of course, the embryo has evolved many mechanisms to get as many resources as it can—our babies are among the greediest out there. So, we have periods because our bodies have evolved to survive our blood-sucking demon fetuses.

That's just a fantastic way of looking at it. But that hasn't been the way that many people have thought about periods. Wasn't there a whole bunch of ideas,



AUTHOR, AUTHOR Cat Bohannon and Lucy Cooke after sharing the stage at the Cheltenham Literature Festival in England to talk about sex, evolution, and the female body.

largely devised by men, about menstruation? What's one that made you chuckle?

The thesis that women synchronize their periods in order not to have sex with men, and therefore the men can go out and hunt and get us food, and I don't know, snacks. And this is the dawn of human collaborative civilization. On the face of it, this is a very bad idea. But it was published in a very reputable place. I don't know what the editor was thinking. I'm not going to say the editor had testicles, but maybe?

Man the hunter has traditionally driven the story of our evolution. He's the great hero and many advances are tied to him. One of those is bipedalism. But you see that differently, too.

When you think about what it is to become upright, from a more tree-based life form, you're thinking about expanding range. And that is usually about food sources. It probably was not hunting big game. We don't have evidence for that until way later, way later.

COURTESY OF LUCY COOKE

I'm not going to say the editor had testicles, but maybe?

We're talking about finding a tasty tuber at the edge of your range.

It's useful to think about who has the greatest need for nutritive resources. Is that going to be the male with the slightly bigger body plan? Or is it going to be a female, who is the primary caretaker in nearly every primate species? Who is also lactating, which is metabolically costly, and is going to require a lot of food to feed the kid. The dawn of bipedalism to me sounded a lot more like single moms with a hungry kid who needs to expand her range.

She has advantages in metabolic endurance to be able to walk that far. And there is evidence that female bodies in humans are better geared for endurance. Endurance runners have more so-called slow-twitch muscle, and speed runners have more fast-twitch. Well, the sex-differentiated balance is clear, even in so-called untrained bodies. Female-typical muscle cells are also better at tapping into different energy substrates when one runs out, versus male muscles. So it's all the way down to the microscopic that we have this endurance advantage.

Another gynecological innovation that you write about is the evolution of reproductive choice in mammals, albeit unconscious choice.

It's always tricky, right? Because what we call choice is so tied to our understanding of human consciousness.

So, what does it mean to choose? Well, it seems clear that female reproductive choice—as it's talked about in biology—is very much a thing. I found it fascinating how many other species of mammals have abortions. And what I'm talking about here is *social* abortions. Humans can have surgical abortions, or you can have miscarriages. But that's not a medical term: That is a *spontaneous* abortion.

There are many species that have a spontaneous abortion in response to a directly observed social change. A mouse is going to do it when she smells the scent of an unfamiliar male while she's pregnant. And she is extremely likely to end that pregnancy and return to her fertility cycle.

You see it in lions, horses, and geladas. It's normal. The mechanisms that drive it are probably a bit different, depending on the species. And the gelada was amazing because now we're in a primate—we're closer to us. They live in that harem-based reproductive group, and the females will abort when a new male does a coup and takes out the old alpha—80 percent of the time. That's a hell of a freakin' signal. And what's interesting to me is that it's usually modelled as fear of infanticide. Because why invest in the baby if it's just going to be killed by the new guy, right? So that's a threat response.

In the gelada what's interesting is there could be infanticide, but it actually seems to be more about social

That's what grandma's for—she remembers where the good hunting is.

tracking, because that new guy can't actually succeed in his coup if he doesn't have the support of the majority of females, right? So, these social abortions are not simply mapping threatened stress in a social environment. Sometimes it is for self-advantage.

Indeed, the gelada females that get pregnant more reliably are those who do have the social abortions. So, there is a reproductive fitness thing there, too. But the idea that it might be tied to social bonding means it's both threat and reward. It's a complex space, and that for me, when I think back now to our very messy, complex, cautious, conscious thing of human primates, it removes this idea that abortion is somehow new and unnatural. It removes this idea that intervening on female fertility in a way that down-regulates our fertility, rather than always trying to be pregnant, would somehow not be true of other mammals and is something only we do. I think only we *consciously* choose the way we do it. But having an abortion response to a perceived change in a social environment, whether for threat or for reward, is something a lot of mammals do.

The female experience has traditionally been wedded to motherhood, as if no other role existed for us. But

that's not always the case. Orcas, for example, are one of the few species that, like humans, go through menopause. The popular theory is that it's so they can help their daughters care for their offspring—the grandmother hypothesis—but you think that's not quite accurate. Tell us about your thinking on menopause.

The grandmother hypothesis holds to the idea that not only does spending a portion of your later life not having babies reduce your competition with your daughters, but also, most importantly, you become advantageous to your daughters, because you're helping take care of the kids. You know, built-in mammalian daycare. It's a great situation, which as a mother of young children, I have a lot of sympathy for.

But orcas are not particularly taking care of the grandkids more. What they mostly seem to be known for is leading the pod to good hunting grounds, particularly when local food sources are running dry. In other words, in a time of nutritive stress, that's what grandma's for—she remembers where the good hunting is. She's also instrumental in teaching younger members of the pod more difficult hunting strategies like lining up like line-backers and creating a bow wave to knock a seal off an ice flow.

So, in general, we expanded our lifespan. That's clear from bones and tooth growth. We had a series of mutations that expanded human lifespan to considerably old age. And the story of menopause is the story of how all human bodies started having a benefit from having the elderly around. I assume it probably required some pretty collaborative societies to have the elderly around. Those societies were probably like unicorns for a very long time. But once you had societies that could support the elderly, one presumes they would benefit from the wisdom of older people.

But the tragic thing about menopause is that women outlive males on the average. And we love men, whether or not we have sex with them. We love trans women and people with these biologically male bodies. If we're lucky enough to live to an old age, we're going to have to say goodbye to them. I think the great impact of menopause is not the hot flashes, it's saying goodbye to your loved ones.

That's definitely the sad side of it. But your emphasis on the fact that menopause is more about a selection for longevity, rather than a selection for a shortening of fertility, is like, boom, yes, that just makes total sense. The idea that I have a role in society for my wisdom, and it was actively selected for, is really empowering. Eve contains a huge amount of wisdom. Well done, you, for plowing forward and writing it. What do you hope will be its legacy?

I hope it gives people more permission to talk about the lived reality of their own bodies. The body is automatically taboo, we are hesitant to speak about it. I hope this book gives readers new frames to talk about what womanhood might be, what parts of it come from where, and what parts don't. I hope scientists and clinicians take up the call to better study the biology of sex differences, because all women are under-studied and under-cared for. We have the power to change that. ☺

LUCY COOKE is a *New York Times* best-selling author, award-winning documentary filmmaker and broadcaster, *National Geographic* explorer, and TED talker with a master's in zoology from Oxford University. Her latest book is *Bitch: On the Female of the Species*.



How Life Really Works

Just as I uncovered a new way to understand life, I got news about my own

BY PHILIP BALL



THE IRONY SEEMED a bit heavy-handed, frankly. Just as I was about to publish a book called *How Life Works*, my own life stopped working as it should.

Following a series of urinary tract infections, a biopsy confirmed that I have prostate cancer. Sometimes this kind of cancer just sits there and does very little, in which case regular monitoring of blood PSA levels is adequate to identify any danger. My cancer isn't like that. It is moderately aggressive and classified as high-risk, which means that a radical intervention—in my case, surgical removal of the prostate—is needed to keep me alive.

Whether that works only time will tell, though the prognosis is hopeful. After the diagnosis but before learning from a PET scan that the cancer appears not to have spread, I was particularly mindful of life's finiteness. Those uncertain days, lit by the golden glow of summer's late dwindling, had a charged intensity. To my surprise, I found solace in what writing *How Life Works* had led me to conclude about the nature of life itself. I am now more amazed by life than ever. Like my late friend Oliver Sacks, my predominant feeling was one of gratitude. Like Oliver, I realized that "being a sentient being on this beautiful planet"—for however long that might continue—"has been an enormous privilege and adventure."

I don't suppose there can be many biologists who, if they delve deeply into the molecular and cell processes that sustain life, have not been astonished that life is possible at all. In *How Life Works*, I open the black box between genes and people, navigating the byzantine details of transcription factors and gene regulation, cell communications and tissue patterning. These are places popular accounts seldom go—and for good reason.

Once we let go—as I believe modern biology shows we must—of the comforting fiction that all this complexity is orchestrated by some master plan in the genetic sequence in our chromosomes, as if simply reading out a recipe, then we have to wonder where the organization comes from. For complex organisms like us, control is decentralized and distributed across many levels, each of them largely insulated from the finer details of what happens on the levels below.

Our atoms are no different to those in rocks and air, and yet here we are.

It's simply bewildering that insensate matter—atoms and molecules, the same stuff from which rocks and air and stars are made—can do this. It is our remarkable good fortune to inhabit such a creative, generative universe, able for a time to spin up little centers of organization that awaken to their own existence.

PRICE OF UNPREDICTABILITY

The idea that our DNA is a “blueprint” or “operating manual” is still popular with agencies such as the National Human Genome Research Institute. But it's an attempt to explain how life works that's out of step with modern biological research and threatens to obscure and even to extinguish the real wonder of the answer.

Life is not about reading out a blueprint, it's about creating flexible rules and resources from which diverse forms might emerge. We all began as a lone fertilized egg: a zygote. That cell made us *us* not just by replicating into something like 28 to 36 trillion cells but by those cells specializing into different tissue types, each with an identical genome but with different suits of genes activated or suppressed. This rich community of cells becomes an organism in a process of constant negotiation and collaboration.

The diversity of cells, as well as the ability of each individual cell to respond to signals from outside (from other cells and the environment), arises through the process called gene regulation: the control of which genes are active, and which are not. When a gene is active, the information encoded in the sequences of DNA building blocks it contains may be read by enzymes and transcribed into a “messenger” RNA molecule, which in turn acts as a template for making a protein. It is generally thought that the complexity of the human body derives not from an abundance of genes—we have far fewer than was thought in the

early 1990s, when the Human Genome Project began, approximately 19,000. (That's barely half as many as a banana.) Rather, this complexity stems from the intricacies with which our genes are regulated.

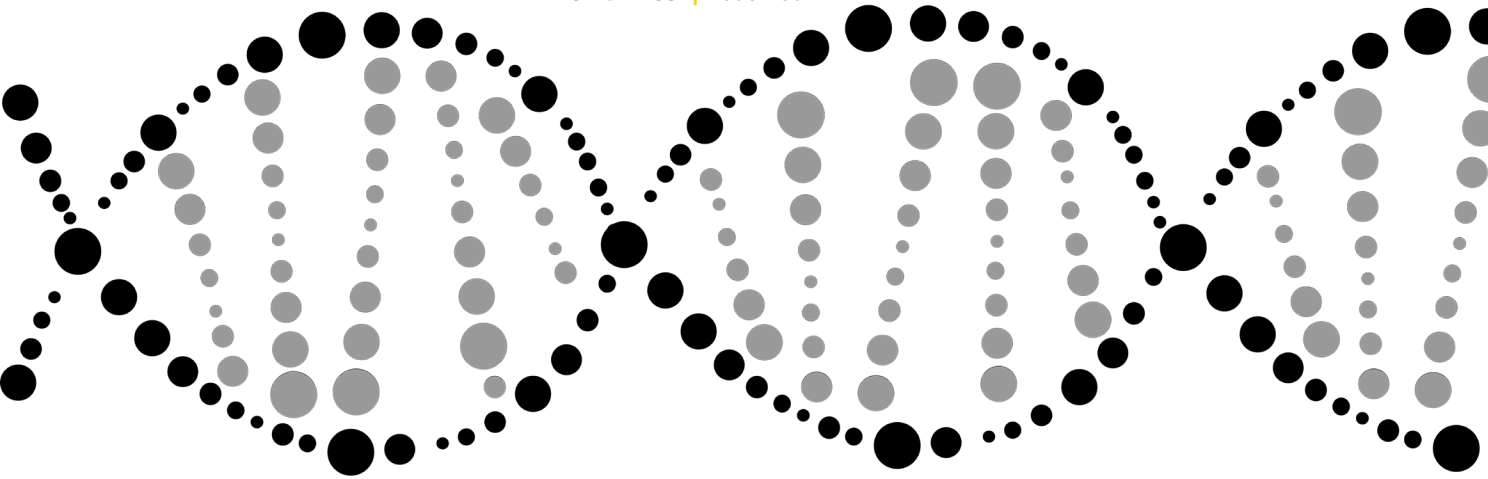
How gene regulation occurs is one of the hardest and most complicated problems for how (human) life works. We now know that it's not simply a matter of our genes having switches that can be flipped on or off by other biomolecules like the switching of transistors in the digital circuitry of a silicon chip. Rather, the logic of gene regulation is fuzzy and collective, involving whole committees of molecules that are none too fussy about who is present or who talks to whom.

Some of the key members of those committees are RNA molecules—not the messenger RNA used to make proteins, but so-called noncoding (nc) RNA. All manner of ncRNAs are now known, some long and some weirdly short and therefore encoding rather little information. With a fair degree of reluctance, biologists have had to admit that some genes aren't there to make proteins at all but to encode these functional RNA molecules.

At first it was thought that such ncRNA genes were mere oddities. But just as the number of protein-coding genes thought to be contained in the human genome decreased over the past three decades or so, so the number of ncRNA genes has grown steadily, to the point where they currently outnumber protein-coding genes. In other words, it seems that the human genome is not even mostly about encoding proteins. This is a remarkable change in the molecular basis of human biology—some might even see it as comparable to our realization that the amount of dark matter in the universe greatly exceeds that of normal matter.

The fuzziness in the mechanisms of gene regulation is reflected in an unforeseen casualness in the way many of the molecules involved interact with one another. For many years, the conventional view in molecular biology was that life's molecules—especially proteins—are exquisitely choosy in their unions with one another and with other molecules, fitting together like a lock and key. That, it seemed, was the only way to keep order amidst the wild throng of the cell.

But it's now understood that many proteins, especially in large, complex animals like us, don't have the well-defined shapes needed for such precise “molecular



recognition.” The molecular chains of which they are comprised don’t necessarily fold up into compact, well-defined forms, but have many segments that stay loose and floppy—“disordered.” This leaves the proteins rather indiscriminately sticky toward one another. That is especially true of those proteins that sit at the hubs of the cell’s interaction networks—the molecules that unite one chain of conversations to another.

Any of these shifts in narrative alone—the importance of gene regulation, the significance of noncoding RNA, structural disorder in proteins, promiscuity of molecular interactions—might be surprising, even perplexing. But taken together, they can be seen to create a new sort of “cell logic” that permits our cells great versatility and adaptability, an ability to respond to one another and to find collective solutions to the noisiness and unpredictability of life at the molecular and cellular scale. This is what makes us robust. It is, indeed, surely what makes us possible at all.

A prescription written into a genome would be too brittle a design for complex, multicellular creatures who occupy such unpredictable and diverse environments. We can see the genes “letting go” as life’s complexity deepens; eukaryotes, and especially metazoans (complex animals), have more of these fuzzy committee-style unions, more protein disorder, more regulatory RNA, than bacteria and other prokaryotes. To risk an anthropomorphism, evolution *chose* to work this way.

But the open-ended nature of the interactions between our molecules and cells has its downside. It means that life can lurch in directions that don’t serve

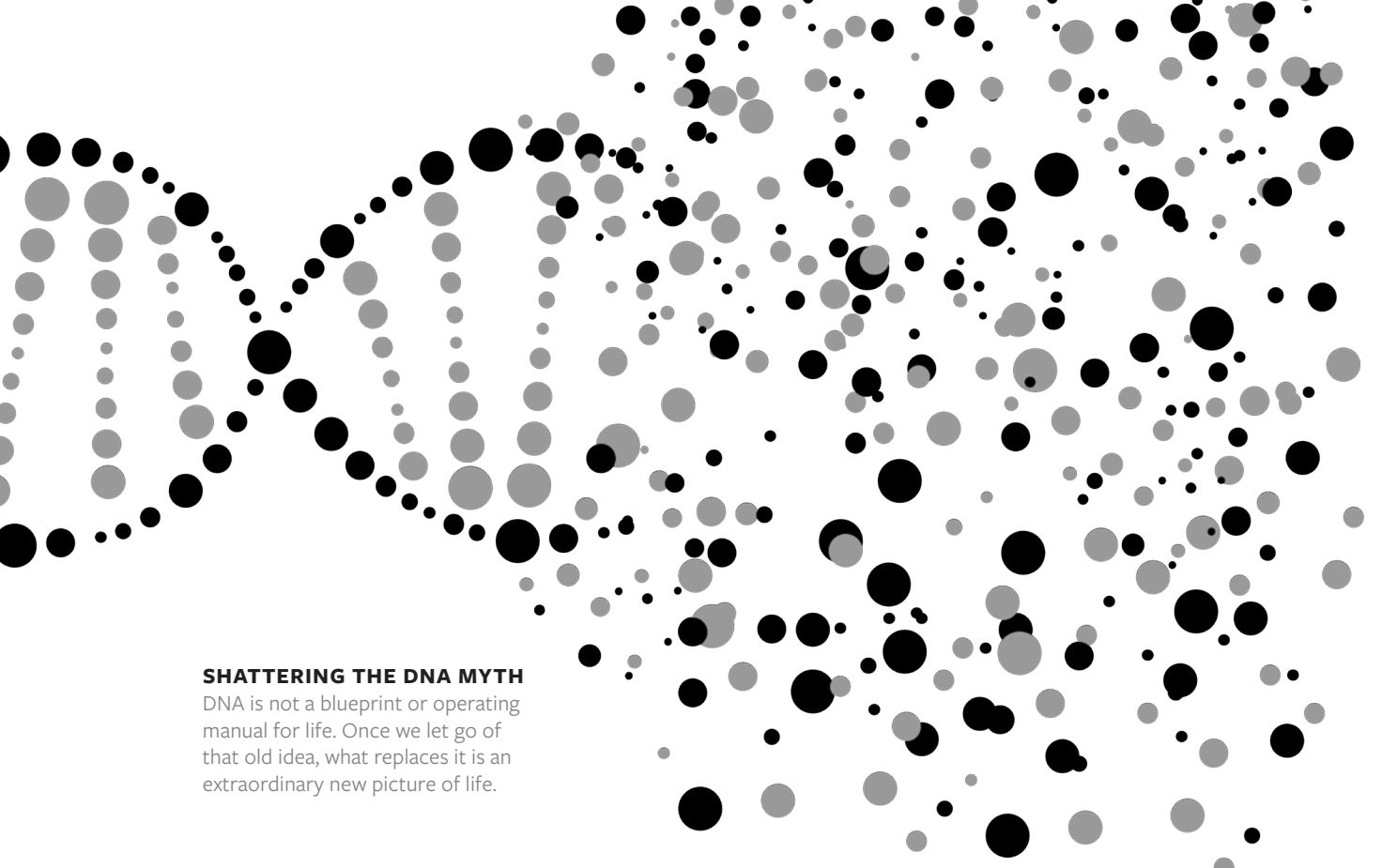
the whole organism so well. The price of keeping the destinations open is that not all of them are desirable.

One example is the way that floppy proteins are apt to fold up and clump together into aggregates that can be toxic to cells. This is particularly common in neurons and can lead to neurodegenerative conditions such as Alzheimer’s and Huntington’s diseases.

Another of the consequences of life’s fuzzy rules is cancer. The dysregulated state of cancer cells is not so much a malfunction as an alternative way for cells to *be*, much as bad weather is something the weather system produces. By the time we reach adulthood, many of us are likely to have some cells in this state: Many, perhaps most, men will die with cancer in the prostate and will never know it. It is as normal to have cancer cells—if not clinical cancer—as to have wrinkled skin or graying hair. You can’t be an organism made from many cells that replicate and self-regulate without incurring that risk.

Yet the cancerous state of cells is not, as once thought, a condition of sheer anarchy, but has its own plan and logic. The fuzzy rules still apply; they just produce a different result. Cancer cells aren’t selfish individualists; rather, tumors typically have complex structures akin to those of normal development. They contain a variety of cell types that can collaborate with—one could say exploit—normal healthy cells to, for example, grow a blood supply. Tumor growth is not a featureless orgy of replication but a kind of deranged development. The derangement can of course kill us.

But once we recognize that cancer is another way for cells to be, we can imagine treatment strategies beyond



SHATTERING THE DNA MYTH

DNA is not a blueprint or operating manual for life. Once we let go of that old idea, what replaces it is an extraordinary new picture of life.

the desperate ones of trying to kill it first by cutting it out of bodies, poisoning it with chemotherapy, or burning it with radiation. One such approach, called differentiation therapy, aims to coax cancer cells into a non-malignant state, just as we can now reprogram our own healthy cells. Another, called immunotherapy, seeks to boost the ability of our immune system to deal with the rogue cells.

Immunotherapy is already proving valuable for treating some cancers, but mine will need to be stopped the old-fashioned way, assisted now by robotics: cutting it out. I don't, however, feel that my cancer is some awful stroke of bad luck, nor some malicious form of life that has taken root inside me. It is part of how life's game must be played. While cancer is not something we are powerless to influence, it's the price we pay for being a complex, multicellular living being.

WE ARE WHIRLPOOLS OF MEANING

Peering in granular detail into the molecular workings of our cells and bodies reveals a new way of thinking about life. But the very ornateness of the baroque

I don't feel my cancer is a malicious form of life that's taken root inside me.

schemes through which life sustains itself points to something larger.

Once we let go of the idea that we are nothing but machines made by genes to perpetuate their existence, what replaces that barren picture is extraordinary, humbling, but also, comforting. Genes must relinquish control to higher levels of organization that provide the cells and the body's ability to adapt. A cell's identity is established collaboratively: Tissues and organs are built by mutual negotiation. As developmental biologist Alfonso Martinez Arias has put it, "cells control genes, not the other way around."

I would modify that statement. In principle, everything in biology can control everything else, depending on the context. I call this *causal spreading*. As organisms evolved increasing complexity, what causes their growth, behavior, and resilience (as well as what causes malfunctions), became spread among the different scales of the hierarchy from genes to networks of genes, from other molecules to cells and tissues. No one level has overall control. We must be able to respond at all levels, so that factors influencing whole tissues or organs can feed back to the genome and determine which genes are active and which are not.

But then what is it, if not a genomic program, that sustains this remarkable balancing act? That's the true mystery. Our bodies, so long as they live, are astonishing feats of organization. Our atoms are no different to those in rocks and air, and yet here we are, a little knot of atoms that can walk around the planet and think about itself and others. This inspires in me, an atheist, the kind of wonder that I suspect many religious believers experience.

To many biologists, this image of life might sound whimsical (at best). That is because, strange though it may seem, most biologists do not concern themselves (or need to) with what life is; they are busy enough trying to figure out how life as we already know it actually works. Life is not, for them, some abstract concept, but rather, the stuff growing in their petri dishes, or moving under their microscope or across the savannah. Yet what in the end keeps all these balls in the air? What manner of phenomenon are we dealing with?

For we are not *merely* a knot of atoms. The atoms that make us are constantly being exchanged with those in the environment, replaced almost entirely every several years. Unlike a lump of rock, in which many of the same atoms have sat there locked into a crystal lattice since before the dinosaurs, we are matter in flux. What exactly is it that stays steady (if not constant) over our lives?

The best we can currently say is that we—each of us as individuals—are self-sustaining patterns that become *imposed* on matter. There's no shortage of

To my surprise, I found solace. I am now more amazed by life than ever.

non-living analogues of structures that are temporarily sustained and organized while matter and energy flow through them: hurricanes and whirlwinds, say. We too are spinning patterns of organization. What makes living things different is that we can modify our behavior and environment to sustain the pattern.

What's more, we can generate new structures and pass on in molecular form a memory that shapes them—the genome, which becomes modified and shaped during evolution by its interaction with its environment. But our DNA is not alive, nor can it somehow “give” life to the whole. Rather, it provides resources and possibilities: no more and no less. Life is the spinning itself, while it lasts.

Our patterns interact and exchange: There is information flow between them. Once we cease clinging to our materiality, as if we were hewn from rock, we can see how there is a genuine spreading-out of the pattern and organization that make us. Some of the patterns in my brain have been set in place by the whirlwinds of meaning who are my family. We are leaky patterns, imprinting onto one another. When I am moved to tears by a Bach prelude, it is not because of some mysterious power of the acoustic vibrations; it is, it can only be, because there is some Bachness preserved in that pattern, some Bach-meaning encoded in the matter of the world.

For what truly distinguishes living organisms as self-organized knots of energy and matter, spinning in the universe, is that they acquire meaning and purpose. Those can often seem like taboo words to many biologists because they convey teleological and even theological connotations. But this is not merely a mistake; it is a fundamental misunderstanding of what life is, of why we are not “nothing but atoms.” Not only can meaning and purpose be scientific concepts, but they *need* to become that if we are to get to the core of what life is.

It is unexceptional, or should be, to say that purpose exists in life. It is also conventional, however, to say that purpose is a mere appearance generated by the tendency of genes to find ways of replicating and multiplying. But the fact that purpose can be dissected into molecules and neurons signifies nothing. So can love, if you try hard enough. Yet still we love.

The physicist Steven Weinberg famously said that the more we understand the universe, “the more it also seems pointless”: It has no meaning. But that is to misunderstand what meaning is: an attribute produced by living things, not one inscribed in the laws of physics. It is no more useful to say that the more we understand the universe, the more humorless it seems. (Some might wryly suspect the opposite, I suppose.) These are not attributes we should seek in the cosmos at large.

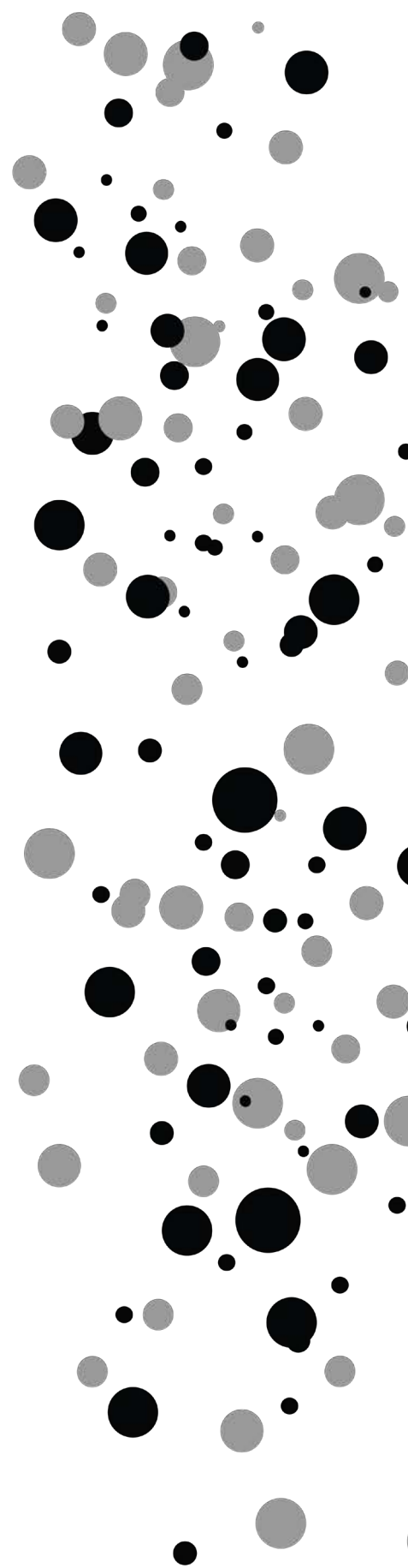
Rather than trying to dissipate life’s purpose and meaning across the cosmos, we can and must make a science of it. It starts with salience: There are things organisms notice and respond to, generally because doing so is beneficial (or expected to be), and other things that they can sense but which they ignore. (The choice of what to sense, meanwhile, is largely made in the process of evolution itself.) They know what matters, by both hard-wiring and experience. By attending to and differentiating what is around them, they create meaning.

Meaning and purpose supply the basis of *agency*: the capacity of living things to act and to change their surroundings to their own benefit. This is perhaps what truly distinguishes what is alive (or is constructed by things that are alive) from what is not. Biology needs to know about transcription factors and cell signaling pathways and the dynamical steady states of cells, but what makes all this a science of life is the existence of agency—and until it has a good theoretical and conceptual grasp of that elusive property, it will not quite be a true science of life.

So we are whirlpools of meaning, and it is both our privilege and our fate that part of our own meaning derives from that of others. We care about one another, and that is what makes it so unutterably sad for us when that cherished other’s spinning ceases, as all self-organized structures do, like Philip Pullman’s characters in the *His Dark Materials* trilogy dissolving into Dust.

As I prepare for surgery, I have every intention of spinning for a good number of years to come. I cannot know how many—which of us does? Yet to be a part of the universe that gets to spin for a time, and to create a unique pocket of meaning: That is indeed something to be grateful for. ☺

PHILIP BALL is a freelance writer based in London, and the author of many books on science and its interactions with the broader culture. His latest book is *How Life Works*.





Elephants Are Total Scaredy-Cats Around Bees

The buzz on preventing elephants from plundering communities

BY CHARLES DIGGES

S THERE ANY KIND OF FENCE that can make humans and elephants good neighbors? It's a question Dominique Gonçalves has had to ponder as she leads the elephant ecology project at Mozambique's Gorongosa National Park, which is not surrounded by a physical barrier.

KEVIN BERGER

A number of pioneering studies throughout Sub-Saharan Africa over the past several years showed a solution that was simple and natural: bees. As it turns out, the tiny, ubiquitous honeybee has the power to terrify a mammal that's 22 million times its size.

In fact, even the sound of the insect's buzz is enough to send a family of elephants into a panic, showed studies by Lucy King, an Oxford zoologist and preeminent researcher in human-elephant coexistence at the non-profit Save the Elephants. Upon hearing the telltale hum, elephants will run, kick up dust, and shake their heads as if trying to swat the bees out of the air, trumpeting distressed warnings to other elephants as they flee.

Of course, a bee's stinger can't penetrate the thick hide of an elephant. But when bees swarm—and African bees swarm aggressively—hundreds of bees might sting an elephant in its most sensitive areas, like the trunk, the mouth, and eyes. And it hurts.

Building on King's insights, Paola Branco of the University of Idaho conducted a massive two-year-long experiment in Gorongosa that culminated in a 2019 paper she co-authored with King, Marc Stalmans, Gorongosa's director of scientific services, Princeton zoologist Robert Pringle, and others.¹ Their research aimed to settle tensions between human farmers and

the park's growing population of marauding pachyderms—with the help of bees.

Although elephants are peaceful by nature, they can and will trample grain, swipe crops, topple down silos, and knock down entire houses. Given half a chance, elephants from the fenceless sprawl of Gorongosa in the Lower Rift Valley will steal across the Pungwe River—which acts as the southern border between the million-acre park and the rest of rural Mozambique—stomping into villages in search of a meal.

Humans share blame in the squabble. Natural habitats for elephants are rapidly being tilled into croplands, encroaching on food sources, often leaving the animals little choice but to ransack and steal. And while the population of African elephants has been precipitously dropping, the number of humans in Sub-Saharan Africa continues to skyrocket, rising from 930 million in 2012 to 1.2 billion in 2022, data from the World Bank show.

The result is that elephants and people are often competing for the same resources. The animals—which typically eat about 300 pounds of vegetation a day—can decimate an entire farm's harvest overnight.

In a way, it's not a terrible problem to have, says Gonçalves, who grew up in the town of Beira, a few hours away from Gorongosa.



BUZZ OFF Buckets of bees are strung on a fence wire along a river in Mozambique. When elephants trip the wire, bees swarm out of the boxes. The elephants hightail back to where they came from.

COURTESY OF GORONGOSA NATIONAL PARK

The Mozambican civil war, which raged from 1977 to 1992, saw 95 percent of Gorongosa's large animals killed. The impact on elephants was especially profound. Slaughtered by warring troops who traded their tusks for more guns, the park's pre-war population of elephants dwindled from 4,000 to only about 200 by the time the conflict ended. Thirty years on, says Gonçalves, that population is bouncing back and now numbers a little more than 1,000. The crop raids are a side effect of that recovery.

But straying elephants cause havoc for small-scale subsistence farmers in Gorongosa's buffer zone, the liminal area that stretches around the 1,500 square miles of the park and is home to more than 200,000 people. The more elephant numbers bounce back, the more of them there are to go on nighttime ransacking missions.

"It's a question of how humans and elephants are overlapping," says Gonçalves. "If there are agricultural plots, that can create situations of conflict, when elephants either eat or trample or destroy. That has a huge economic security impact for farmers."

Most subsistence farmers don't have the resources to surround their plots with expensive wire fences, and often must resort to less effective deterrents like banging sheet metal to scare elephants away, burning tires to produce acrid smoke, or lying in wait in the bushes at night with flashlights and fireworks to startle the animals.

These confrontations can prove lethal for both sides. In July of 2022, five people harvesting their crops in the Mozambican province of Cabo Delgado—870 miles northeast of Gorongosa—were trampled by elephants from the Quirimbas National Park. On occasion, humans retaliate. In Kenya, for instance, wildlife authorities shoot between 50 and 120 elephants per year.



LIVING FENCES Dominique Gonçalves, manager of the park's elephant ecology project, says that using beehives as an animal deterrent is "a beautiful idea." It not only stops elephants from destroying crops, it provides people with the sweet reward of honey.

"That's the worst-case scenario," Gonçalves says. "Both people and elephants end up being dead." So she and her colleagues at Gorongosa decided to intervene to keep the two sides happy.

It began, as many science things do, with an experiment. In 2017, researchers strung a series of fences at well-trafficked elephant crossing points along the Pungwe River. Some of the fences relied on methods

of elephant deterrent already popular among small-scale farmers, such as twine soaked in chilis.¹ But between others, the researchers ran bailing twine from which they suspended hives populated by the famously irascible African bee, a species nearly identical to its European and North American cousins—but for its more aggressive tendencies. Still others combined chili-coated twine *and* bee hives.

The researchers then tranquilized and fitted 12 male elephants—males being more apt to forage in crop-lands—with GPS collars. Satellite data pinged from the collars, combined with the observations of local community members, allowed the researchers to keep exacting tabs on where the elephants wandered and whether the experimental fences prevented them from stumbling into neighboring farmsteads to rummage.

Sure enough, the fences worked. The chili fences reduced elephant river crossings by 80 percent—while the beehive fences thwarted a whopping 95 percent of cross-river forays by the animals. (Beehives strung on twine coated in chilis were, surprisingly, the least

The bee has the power to terrify a mammal that's 22 million times its size.

effective. King and her co-authors surmised that the coating weighed the twine down, making it easier for elephants to simply step over it.)

Cameras placed near fences involving beehives showed that the elephants would trip the bailing twine, thus shaking the suspended beehives. Immediately, this would stir the bees to action, and they would swarm and mount an attack. In footage taken at night, shadowy silhouettes of peeved elephants can be seen turning tail and lolloping in unison out of the frame.

The true beauty of this method, write Branco and her coauthors in the study, is that it allows discontinuous fencing to block key corridors used by elephants as they go on crop raids rather than fencing individual farms or entire nature preservers, like Gorongosa—which both for the farmers and the park could prove prohibitively expensive, running into the thousands and even tens of thousands of dollars. To build 15 hives and string them from posts, Branco and her team spent a total of \$773.

The results at Gorongosa jibed with those from another field study that King conducted in Kenya in 2017.² In that experiment, researchers strung beehive fences around 10 farms that were located near a nature preserve, reducing elephant raids by 80 percent. Bee fences have also been found to be an effective deterrent against crop raiding Asian elephants, showed a 2018 study King conducted in Sri Lanka.³ In that case, merely playing recordings of angry bees through speakers in the field was enough to cause the elephants to flee.

Gonçalves says the bee barriers set an important precedent for future conservation efforts by offering a nonlethal method of control that doesn't create divisions between the park and the people who live near it.

Bee fences alone aren't enough. Other animals that are less flustered by bees, such as baboons and honey badgers, can be drawn to the honey the bees produce, disturbing the hives to the point at which the bees themselves take flight and move out. King's studies

in Kenya, however, suggested that small cages can be placed around hives to prevent them from being disturbed by these other foragers. The dry seasons, too, can dampen bee populations in hives as they flee and search for moister climes.

But the elephant intellect, says Gonçalves, proves the biggest obstacle to a static set of beehive fences. They have not, for instance, deterred clever elephants from seeking out alternative crossing points and taking up near-permanent residence in the buffer zone.

Indeed, Stalmans says, sometimes a traditional, or even electric, fence is the best resort—but even those prove, over time, to be no match to an elephant's keen navigational sense. Just as they are smart enough not to get stung or shocked, they're also smart enough to simply chart routes around most human-made impediments and find their way to nearby farm settlements.

It is here that Gonçalves joins efforts with Gorongosa's human-wildlife coexistence team. Together, they chart the peregrinations of known elephant families that have been collared with GPS devices and can thereby spot areas of potential human-elephant conflict before they erupt. 🐝

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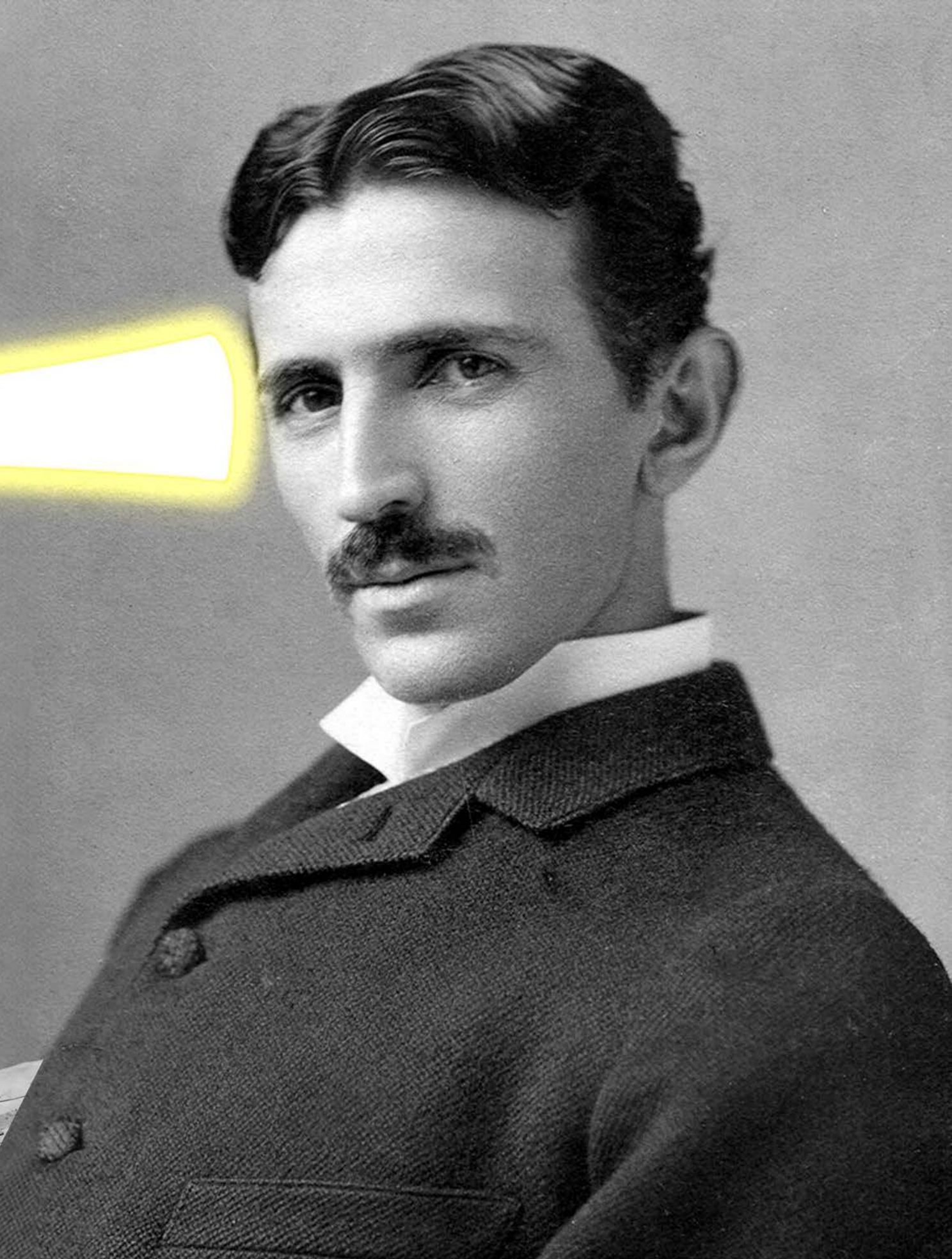
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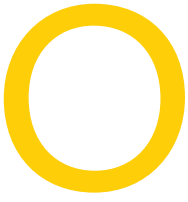
Tesla's Pigeon

An inventor, a bird, and a plan to connect all the minds in the world

BY AMANDA GEFTER







IN A FEBRUARY MORNING IN 1935, a disoriented homing pigeon flew into the open window of an unoccupied room at the Hotel New Yorker. It had a band around its leg, but where it came from, or was meant to be headed, no one could say. While management debated what to do, a maid rushed to the 33rd floor and knocked at the door of the hotel's most infamous denizen: Nikola Tesla.

The 78-year-old inventor quickly volunteered to take in the homeless pigeon.

"Dr. Tesla ... dropped work on a new electrical project, lest his charge require some little attention," reported *The New York Times*. "The man who recently announced the discovery of an electrical death-beam, powerful enough to destroy 10,000 airplanes at a swoop, carefully spread towels on his window ledge and set down a little cup of seed."

Nikola Tesla—the Serbian-American scientist famous for designing the alternating current motor and the Tesla coil—had, for years, regularly been spotted skulking through the nighttime streets of midtown Manhattan, feeding the birds at all hours. In the dark, he'd sound a low whistle, and from the gloom, hordes of pigeons would flock to the old man, perching on his outstretched arms. He was known to keep baskets in his room as nests, along with caches of homemade seed mix, and to leave his windows perpetually open so the birds could come and go. Once, he was arrested for trying to lasso an injured homing pigeon in the plaza of St. Patrick's Cathedral, and, from his holding cell in the 34th Street precinct, had to convince the officers that he was—or had been—one of the most famous inventors in the world.

It had been years since he'd produced a successful invention. He was gaunt and broke—living off of debt and good graces—having been kicked out of a string of hotels, a trail of pigeon droppings and unpaid rent in his wake. He had no family or close friends, except for the birds.

And one in particular.

He told his biographer, John O'Neill, the story himself. "I have been feeding pigeons, thousands of them, for years," Tesla said. "But there was one pigeon, a

beautiful bird, pure white with light gray tips on its wings; that one was different. It was a female. I would know that pigeon anywhere. No matter where I was that pigeon would find me; when I wanted her I had only to wish and call her and she would come flying to me. She understood me and I understood her. I loved that pigeon. Yes, I loved that pigeon."

Tesla said that he and his bird could speak to one another mind to mind, and that sometimes, as they silently conversed, beams of light would shoot from her eyes.

It would be easy to dismiss the pigeon chapter of Tesla's life as a bizarre or pathetic turn of events: the once-great engineer who wowed the world with dazzling displays of electricity, whose inventions shaped the way currents ran through our cities and electrified our homes, descending into loneliness or madness, believing himself to be in a romantic relationship with a telepathic bird.

But in doing so, we'd miss something critical. For it wasn't really a turn of events at all. In a way, they were all of a piece—the blazing currents, the ingenious inventions, the notion of conversing mind to mind—in a moment in time when the universe suddenly had been turned on its head, when the discovery of invisible waves from the electromagnetic spectrum opened up strange new spaces, and the line between the possible and the impossible cut the shape of a wing.

TESLA'S LOVE OF PIGEONS was an obsession with a capital O. Likely followed by a capital C and a capital D. He seems to have suffered from obsessive compulsive disorder, and his case was severe. As a child, he described, "I contracted many strange likes, dislikes and habits." Dislikes included: anything too round ("the sight



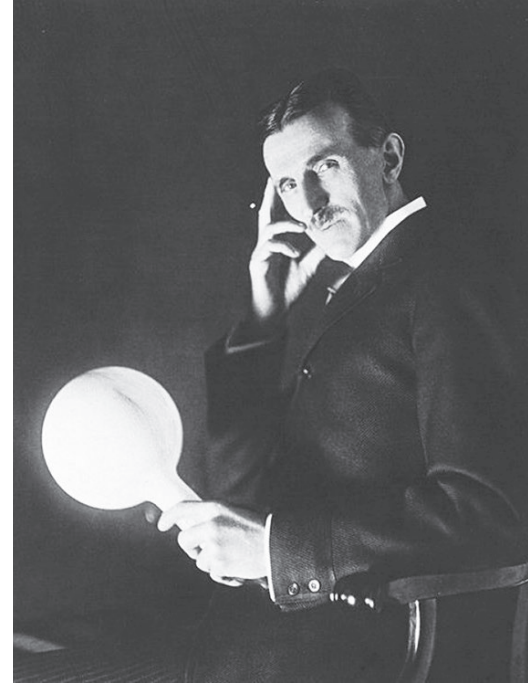
of a pearl would almost give me a fit”; “I would get a fever by looking at a peach”) and touching another person’s hair (“except, perhaps, at the point of a revolver”). Likes included: doing things in threes (hence his hotel room on the 33rd floor). As for habits, there was counting: the steps in his walks, the cubical contents of his soup. “If I missed I felt impelled to do it all over again,” he recalled, “even if it took hours.”

He was, from an early age, tormented by intrusive thoughts, a textbook symptom of OCD, though his were extreme: ideas and images that gripped his mind with such unrelenting force they bordered on hallucination. They were often accompanied by flashes of light, the air around him “filled with tongues of living flame.” At times, Tesla’s perceptions seemed to be amplified. “I could hear the ticking of a watch with three rooms between me and the time-piece. A fly alighting on a table in the room would cause a dull thud in my ear,” he wrote in his autobiography.

These experiences shaped the way Tesla thought about thought itself. Because he had little control over them, he felt them to be coming from the outside, as if he were picking up unwanted signals from the world around him. Soon he grew convinced that *all* thought came from the outside—that our brains pluck images, ideas, and inventions from the environment. “The brain is not an accumulator as commonly held in philosophy,” he decided, “and contains no records whatever of a phonographic or photographic kind. ... The brain has merely the quality to respond.” If only he could figure out how the brain decides which signals to tune into and which to keep out or why some were magnified to such terrifying proportions, he thought, we might finally understand the workings of the mind, and he might finally feel connected to other people and at home in the world.

AS A YOUNG MAN Tesla’s mind was widely celebrated as among the brightest of his time. At 26 years old in 1882, Tesla conceived of the alternating-current motor. When it was perfected and built six years later, Tesla’s motor completely redefined how one could use electric currents to induce motion.

Existing motors required mechanical parts to keep their rotors turning in one direction. Those parts were subject to friction—they sparked and wore down; they were a drag on efficiency. In an epiphany, Tesla realized that he could replace those physical parts with electrical currents. Most engineers at the time worked with direct current, which flows in one direction, but Tesla saw the potential of alternating currents, which reverse directions, flowing back and forth. The key, he realized, was to use multiple alternating currents that were out of step with one another. That way, their voltages could cancel out at just the right moments to produce a combined magnetic field that would steadily rotate, causing the rotor to spin. The relationship between currents could do the work of a machine.



IN THE AIR Nikola Tesla (sometime around 1898) holds a lightbulb several feet away from a generator, and it nevertheless continues to shine. The late 19th century was a time when light, power, messages, and voices could suddenly be summoned from the ether—there seemed no reason to think this fantastical progression should stop short of brainwaves and thoughts.



Tesla said that he and his bird could speak to one another mind to mind.

“It was a fundamentally brilliant insight,” says W. Bernard Carlson, a historian of technology at the University of Virginia. “To this day, all alternating current motors, whether in the hard drive of your computer or your refrigerator or an elevator, follow the same basic principle. Before Tesla, you only had electric lighting. After Tesla, you could have electric light *and* power.”

Tesla, though, had something much bigger in mind. It began with the Tesla coil, which he designed in 1891. He had set out to create an induction coil (a device in which the electrical current in one coil of wire induces a current in a second coil of wire) when he realized what would happen if this time the currents were in sync. By adjusting the lengths of the coils so that their electrical vibrations aligned, Tesla discharged a rip-roaring spark.

This was the phenomenon of resonance—the same principle that explains how tuning forks ring and sympathetic pendulums swing, why there’s music in the harmony of the spheres. Tesla turned it into an engineering principle. And he saw that it stood to solve a problem that was vexing science.

In 1865, James Clerk Maxwell had unified electricity and magnetism, showing that visible light was an

electromagnetic vibration—and that there could be others. Only with the discovery of radio waves by Heinrich Hertz, in 1888, did it dawn on scientists that there existed an entire electromagnetic spectrum that was, in principle, infinitely vast. At the lowest end of the known range, radio wavelengths could span the planet, while a wavelength of visible light might be 100 times smaller than the width of a human hair, and gamma rays, in the upper register, vibrated on the scale of atomic nuclei. Wilhelm Röntgen’s 1895 discovery of X-rays only furthered scientists’ feeling that the universe had cracked open and that a brave new world was spilling out. The British newspaper *The Standard* reported that “the universe was full of different sorts of vibrations, of which [scientists] had not the remotest knowledge or slightest suspicion”—waves that could cut through a London fog, and rays that could pass through buildings and bone.

In a few short years, the world had grown infinitely richer, full of mysterious new possibilities. The question was how to access and utilize those vibrations. What was needed, said physicist William Crookes, who did pioneering work on electron beams, were



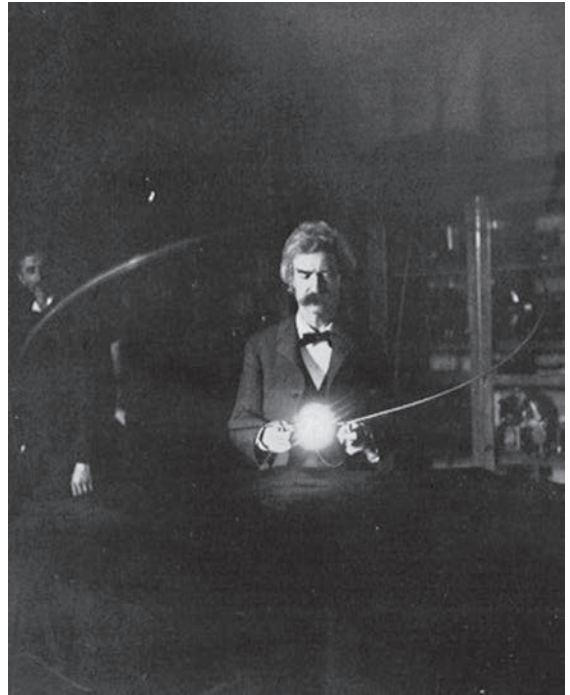
“more receivers which will respond to wavelengths between certain defined limits and be silent to all others.” This, he said, is “the most difficult of the problems to be solved.”

Tesla saw the solution in resonance. When the alternating currents in his coils vibrated in sync, they not only produced sizzling sparks, they also emitted radio waves—attach an antenna and you’ve got yourself a radio transmitter. By tuning the coils, Tesla could choose the frequency of the emitted waves. In turn, those tuned coils, exposed to radiation coming *in* through the antenna, would only respond to waves of the resonant frequency. The Tesla coil could serve as a tuned receiver.

“Tesla was one of the first to really understand this idea of tuning,” Carlson says. “His big insight was that radio waves could be resonant phenomena.” Tesla’s coil was a potential solution not only to Crooke’s problem but also, Tesla hoped, to his own—to the problem of how his brain tuned in to the world.

THE STUDY OF ELECTRICITY and the nervous system had always gone hand in hand. The first measurements of moving current were made in the 18th century by Luigi Galvani, who connected a frog’s nerve to a long metal wire and held it up to a stormy sky, channeling electricity from the air; when lightning flashed, the frog’s muscles contracted. Alessandro Volta modeled the first battery on the nerves of the electric eel; Samuel Morse used that battery to power his electric telegraph lines, then turned right back around and compared his telegraph to living nerves. An 1837 article in *The Scotsman* expounded on the possibilities of cities linked by “electric nerves”: “Men a thousand miles from each other would be enabled to confer as if they were in the same apartment, or to read each other’s thoughts as if they were in the sky.”

Just as the first electrically coded messages were being sent along telegraph wires in the 1840s, the first precise measurements of electrical activity in neurons were being made. So when Hertz discovered radio waves traveling wirelessly through the air, a new neural concept suddenly became possible; perhaps there were also “brain waves.”



GREAT MINDS Mark Twain was a frequent visitor to Tesla’s lab. Here he is seen, around 1895, illuminating a lightbulb from current that is being run through his body; Tesla looks on from the dim behind him. Tesla’s ideas were infectious: “We must have the *thought* itself shot into our minds from a distance,” Twain told *Harper’s Monthly*.



Before Tesla, you only had electric lighting. After Tesla, you could have electric light *and* power.

If accelerating charges in a wire could induce wireless vibrations in the ether, scientists thought, surely sparks in neurons could, too. “Brain waves are fashionable in London at this moment,” read an 1897 edition of the *Boston Evening Transcript*, reporting on remarks by Crookes. “His brain wave theory is only an extension of the law governing the vibrations of sound and light.” The idea was that somewhere in the vast and unexplored electromagnetic spectrum one could find *thought*.

“The discovery of wireless radio made people rethink the basic ideas of consciousness,” says Anthony Enns, a researcher at Dalhousie University in Nova Scotia who studies the history of technology and its relation to pseudoscience. “Crookes was fascinated by the idea of the brain as a kind of radio transmitter and receiver,” while Oliver Lodge, one of the pioneers of radio, “saw consciousness as a kind of energy field that was not located in the brain but surrounded the brain.” If thoughts generated brain waves, why couldn’t other minds pick them up? “The air is as full of brain waves as it is of sunbeams and starlight,” penned one newspaper reporter of the time.

The distance between humans seemed to be shrinking, and the possibility of thought transference seemed

an increasingly natural outcome of Maxwell’s theory of electromagnetism. The writer Mark Twain who was known to hang out in Tesla’s lab, told *Harper’s Monthly*, “The telegraph and the telephone are going to become too slow and wordy for our needs. We must have the *thought* itself shot into our minds from a distance. ... Doubtless the something which conveys our thoughts through the air from brain to brain is a finer and subtler form of electricity, and all we need to do is find out how to capture it and how to force it to do its work, as we have had to do in the case of electric currents. Before the day of telegraphs, neither one of these marvels would have seemed any easier to achieve than the other.”

The great inventors were hard at work, trying to be the first to build this mental telegraph. Alexander Graham Bell, for one, constructed helmets made of coiled wires, which two people could wear, one transferring their thoughts to the other. The result? “The thought in one brain has produced a sensation in the other, through the two helmets, but what the relation was between the thought and the sensation could not be determined,” Bell reported to *McClure’s Magazine* at the time.

Tesla proposed a technology that went beyond transmitting mere thoughts. He called it “television”—not to be confused with what we now know as



television—by which one could “see at a distance” what another person was seeing in their mind. He figured that since vision involves excitations running from the retina up to the brain, perhaps imagination involved signals traveling from the brain back down to the retina. With a device capable of reading those signals off the retina, Tesla explained, “we may finally succeed in not only reading thoughts accurately but reproducing faithfully every mental image.” We could even “project the images conceived on a screen and render them visible to an audience,” he said. He assured the world that he was working on it.

Tesla didn’t subscribe to spiritualism; he didn’t believe in the psychic or the supernatural, though plenty of high-minded scientists of his time did, including the likes of Lodge and Crooke. Tesla described his own view of the universe as “grossly materialistic.” And yet he could wish for his pigeon and she would come; he could understand her through the lights from her eyes.

If such things seem contradictory, it’s because that moment has come and gone, a time when the line between the material and the mental was hard to make out, when matter and mind both had their places upon the same electromagnetic spectrum, a spectrum with infrared and radio at one end, visible light somewhere in the middle, along with fear and love, hope and X-rays, and gamma rays in the far reaches, along with imagination and ideas.

It was a period in the history of science when previously unimaginable ideas were coming not just into focus, but fruition. At the dawn of the 1840s, there was no telegraph, no phonograph, no radio, no phone. By 1901, disembodied voices could be summoned from the ether; messages could be sent across the ocean, surfing electromagnetic waves. It was enough to leave the public dizzy and scientists speculating. “When there’s a new scientific discovery that throws in the air our old scientific concepts, then a lot of extraordinary theories

THE GREAT CONNECTOR

Tesla dreamed of an Earth-spanning system that would use electromagnetic resonance to connect all humans on the planet. The first node was to be a giant Tesla coil-like tower constructed at Wardenclyffe. Pictured here around 1902, the installation was never completed and was later demolished and sold for scrap.



Tesla was going to “convert the entire Earth into a huge brain.”

can be entertained,” says Enns of this period of electromagnetic magical thinking. The line between science and pseudoscience becomes difficult to draw.

The current, Enns says, can also flow both ways: “Unorthodox ideas can end up directing what we do in our legitimate scientific practices.” In 1924, the German psychiatrist Hans Berger set out to prove the existence of telepathy by measuring brain waves emanating from the skull. “His idea was that if you could record these electrical impulses, it would show that the brain was a communication device,” Enns says. So Berger invented the electroencephalogram (EEG), a foundational technology of modern-day neuroimaging. We no longer think of our brains as wireless telegraphs or thoughts as things that can be transmitted by brain waves; now we think of brains as computers and thoughts as things that can be uploaded to the cloud. “These ideas have not really gone away,” Enns says.

For Tesla, nerves in the brain had to work by the principle of resonance, which meant thoughts were things we could all tune into, given the right device. If he could create a technology that would allow everyone around the globe to resonate with one another, it “would be of inestimable consequence on all human relations.” Especially his own.

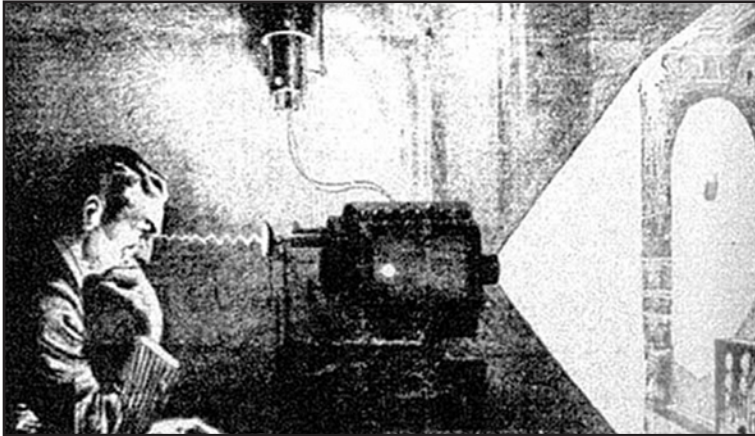
So that was his plan. He was, as he put it, going to “convert the entire Earth into a huge brain.”

AT THE TURN OF THE CENTURY, and the height of his fame, Tesla announced his plans to create a “World System” that would unite in literal harmony the entire globe, allowing people everywhere to send energy and information to be received by anyone, anywhere else.

Other scientists were also experimenting with wireless radio communications, sending electromagnetic waves between grounded transmitters and receivers. The assumption was that the signals were traveling through the air, while the ground currents merely completed the circuit. But Tesla was convinced they had it all backward—there was no way, he said, that the signal would make it through the air for long distances. Light waves travel in straight lines, but the Earth is curved—the information would be making a beeline for outer space. No one at the time knew that radio waves would run up against charged particles in the ionosphere and reflect back.

So Tesla figured that the messages had to be going through the ground. The Earth, he thought, must be a resonant cavity that could host standing waves of electrical vibrations—waves that could be plucked like guitar strings. If he could pump in energy at the Earth’s





MIND POWER If Tesla could summon and channel electricity through the air, could not the recently discovered electric brain waves also be transmitted? He conceived of a system, illustrated here for a newspaper around 1933, that would capture pictures from the mind's eye and project them for others—a technology he dubbed “television.”

resonant frequency, he could set the electrical activity of the entire planet aquiver, and use it to transmit messages or power between any two points on the globe.

In 1901, on the northern shore of Long Island, at a site called Wardencllyffe, Tesla erected a 187-foot mushroom-capped tower while the locals looked on bemused. From the base of the tower, a circular staircase wound down to a well 120 feet below the surface, from which there extended an array of iron pipes and four stone-lined tunnels, 100 feet apiece, where the electricity would be pumped into the ground. To the press he promised that a system of such towers—giant Tesla coils, in effect—would connect all existing telegraph exchanges. It would allow government agencies to send secret messages, which no spy could intercept. It would integrate all the phone lines, create a global news media, link up the world's stock tickers, distribute sermons around the globe. It would synchronize clocks; transmit images, text, and music; it would provide a global navigation system to steer the ships, and energy to power them. It would send messages—person to person—in a flash, to “an inexpensive receiver, not bigger than a watch.” It would broadcast the thoughts from one's retinas to whoever else wanted to see them. And, more than anything, it would make Tesla a little less lonely.

Tesla's OCD had shaped his thinking about thinking, sparked his interest in resonance, and molded the form of his inventions—but it also left him

disconnected and alone. He didn't like to shake hands and often wore white gloves when out in public. He ate by himself at a special table that no one else at the hotel was allowed to use. As his biographer O'Neill noted, “A fresh table cloth was required for every meal. He also required that a stack of two dozen napkins be placed on the left side of the table. As each item of silverware and each dish was brought to him—and he required that they be sterilized by heat before leaving the kitchen—he would pick each one up, interposing a napkin between his hand and the utensil, and use another napkin to clean it. He could then drop both napkins on the floor. Even for a simple meal, he usually ran through the full stock of napkins.” If a fly landed on the table, they had to remove everything and start over. If a woman nearby wore pearls, it put him off his food.

But if the tower worked, he'd be able to connect to other people, to *all* people; he wouldn't even have to wear his white gloves. As a child, Tesla played a game with his father where they'd try to guess the other's thoughts. With the tower, no one would have to guess. It wasn't so much that they could read each other's individual minds. It was that they'd all be thinking together, multiple currents moving in and out of step, the invisible cogs and gears of a single brain. “These ties we cannot see, but we can feel them,” he wrote. In the world of the tower, we would cease to be isolated individuals—for a resonance is always a relationship.



By 1902, the tower was completed, but the rest of the site wasn't, and he was running out of funds. A year later, it became clear that no money was coming, and Tesla had nothing to show for the project, no evidence that the thing would work, and no way to attract new investors. Frustrated, he cranked up the coil, discharged a storm. "The air was filled with blinding streaks of electricity," the *New York Sun* reported, "which seemed to shoot off into the darkness on some mysterious errand."

Today, scientists largely agree that Tesla's tower, even if completed, would never have worked. "He thought that he could transmit power through the Earth with no losses because the Earth would function like an inelastic medium," Carlson explains, "but it doesn't." It was a beautiful idea. The real world simply didn't match up with his grand vision.

It was a failure from which Tesla never recovered.

In the years that followed, he became more of a recluse. Once in a while, he'd make some wild pronouncement or another to the press—death rays and flying machines, a plan to send power to the moon—more inventions he'd dreamed up but for which he had nothing to show. The public grew impatient. Science moved on without him. "He was a broken man," Carlson says.

In December of 1916, Tesla was to receive the prestigious Edison Medal from the American Institute of Electrical Engineers "for meritorious achievements in his early original work in polyphase and high-frequency electric currents"—emphasis on the "early." The ceremony was held just steps from Bryant Park. But when Tesla was meant to take the stage, he was nowhere to be found. The engineers looked everywhere—the hallways, the restrooms—before rushing outside. In the plaza of the public library just adjacent, as O'Neill described it, "in the center of a large thin circle of observers stood the imposing figure of Tesla, wearing a crown of two pigeons on his head, his shoulders and arms festooned with a dozen more, their white or pale-blue bodies making strong contrast with his black suit and black hair, even in the dusk. On either of his outstretched hands was another bird, while seemingly hundreds more made a living carpet on the ground in front of him."

Eventually, Tesla went back inside and accepted his medal. The tower at Wardencliff was dynamited and sold for scraps.

BEFORE THERE WERE TOWERS—before there was radio, before there were telegraphs—there were pigeons. Homing pigeons, prized for their exceptional navigation, had been used to transmit messages since the days of Julius Caesar. A well-trained bird could fly 600 miles without stopping, averaging 60 miles an hour at a pace. In wartime, they served in the Army, the Navy, the Air Force, the National Guard; even the U.S. Forest Service and CIA employed pigeons. When Paris was under siege by the Prussians, homing pigeons carried critical notes in and out of the city; using microphotography, the French could fit thousands of messages in the legband of a single bird. In the United States, pigeons flew news stories and stock prices. Papers like the *New York Sun* and the *Boston Daily Mail* relied heavily on pigeon post; the *Baltimore Sun* flew 500 birds between New York City and Washington, D.C.

But when Guglielmo Marconi, using a system of Tesla's resonant circuits, transmitted the first wireless radio signal across the Atlantic in 1901, the pigeons were suddenly in trouble. "Marconi Beats Pigeons," read the headline of *The Brooklyn Daily Eagle*: 200 homing pigeons employed by the Brooklyn Navy Yard to communicate with warships were about to be out of work. "It is thought that the Marconi system can be maintained as cheaply as the pigeon system," the article reported.

So the unemployed ended up astray in the streets. And Tesla, whose inventions had put them out of a job, took them in.

"Sometimes I feel that by not marrying I made too great a sacrifice to my work," 70-year-old Tesla told a reporter, "so I have decided to lavish all the affection of a man no longer young on the feathery tribe. I am satisfied if anything I do will live for posterity. But to care for those homeless, hungry, or sick birds is the delight of my life."

And the white pigeon in particular seemed to stir something in him.

"If she needed me," Tesla said, "nothing else mattered. As long as I had her, there was a purpose in my life."

"One night as I was lying in my bed in the dark, solving problems, as usual, she flew in through the open window and stood on my desk," Tesla told O'Neill. "I knew she wanted me; she wanted to tell me something important so I got up and went to her. As I looked at



her I knew she wanted to tell me she was dying. And then, as I got her message, there came a light from her eyes—powerful beams of light. Yes, it was a real light, a powerful, dazzling, blinding light, a light more intense than I had ever produced by the most powerful lamps in my laboratory. When that pigeon died, something went out of my life. ... I knew my life's work was finished."

On Jan. 7, 1943, at 10:45 pm, Nikola Tesla was found dead in his room by a hotel maid. "For forty years," read the obituary that ran in *The New York Times*, "he lived and worked in a world of fantasy crackling with electric sparks, packed with strange towers to receive and emit energy and dreamy contrivances to give utopian man complete control of nature. It was a lonely life." A spokesman for the hotel said that "Dr. Tesla died as he had spent the last years of his life—alone."

Only he wasn't alone—not likely. He always kept the window open.

TODAY, WIRELESS TECHNOLOGY performing nearly every dream Tesla had is in our back pockets, connecting us through that unseen spectrum, in devices, indeed, not that much bigger than a watch. But the homing pigeon remains an enigma.

How does it navigate? Does it use its powerful sense of smell? Its acute vision? Can it hear in infrasound? The U.S. Navy, in the 1950s, funded research to see if it homed by ESP. Scientists mostly agree that the birds can sense the Earth's magnetic fields—but how? Researchers thought they found magneto-sensors in their beaks, only they turned out to be white blood cells. Now they think they're in the brain stem, or maybe the inner ear.

A few years ago, some biologists in Spain decided to test whether exposing them to powerful magnetic fields would throw off their compass. They put the pigeons in an MRI—a magnetic resonance imaging machine—with a strength of three Teslas.

Upon release, the birds struggled to find their way. The controls, on the other hand, headed home—mysteriously tuned into some invisible vibrations. 🌀

AMANDA GEFTER is a science writer and the author of *Trespassing on Einstein's Lawn*.





The Astrophysicist Who Loves the Things We Cannot Know

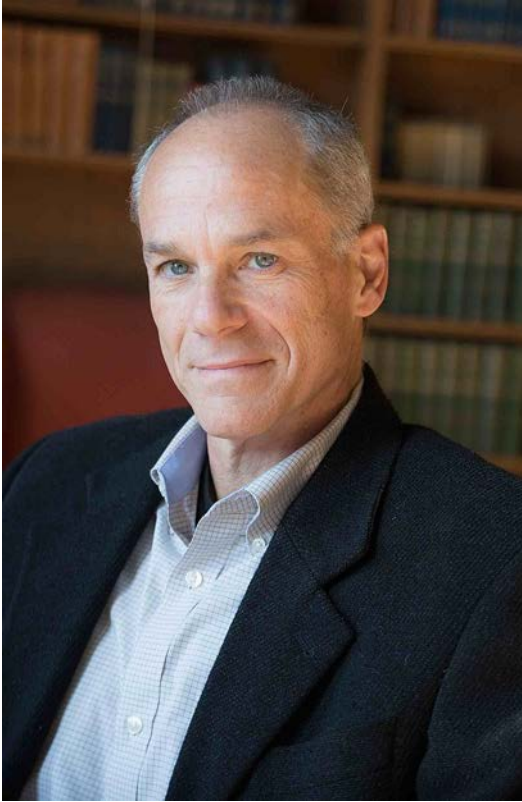
*A conversation with “rational mystic,”
physicist Marcelo Gleiser*

BY ANNE STRAINCHAMPS



MARCELO GLEISER THINKS we have the story of the universe all wrong. And that it's time to restore Earth and humanity to the center of the cosmos. The Brazilian physicist, astronomer, and winner of the 2019 Templeton Prize thinks modern science has fallen prey to an increasingly bleak perspective—a view of Earth as an insignificant speck alone in a cold, dark universe.

Gleiser, a noted theoretical physicist who teaches at Dartmouth College, has published a string of books on high energy physics, cosmology, and the origins of the universe. In his latest, *The Dawn of a Mindful Universe: A Manifesto for Humanity's Future*, he writes that ever since Copernicus, “the more we learn about the universe, the smaller and less important planet Earth seems.” It's a toxic narrative, he thinks, that set the stage for reckless use and abuse of the planet's resources. There aren't that many writers who could make the story of the Big Bang, expansion of the universe, and galaxy formation relevant to fossil fuel consumption and the climate crisis. In Gleiser's hands, the story of the universe becomes a call to action.



SEEKER OF UNCERTAINTY Astrophysicist Marcelo Gleiser grew up amidst spiritualism in Brazil. As a scientist, he still finds echoes of these sentiments in his work—from Einstein’s writings to new theories about the beginning of our universe.

In a recent conversation, he seemed energized by the flood of new data raising questions about the current model of the universe—and by the very real possibility that humans will never truly understand the universe, a lesson he felt personally after a devastating loss in childhood.

You have argued that findings from the James Webb telescope are calling the story of our universe into question. What, specifically, makes you think cosmology may be due for a conceptual revolution?

We always thought stars were made when the universe was about 100 million years old. So the usual narrative is that first you have a bunch of big, big stars. They collect, they form black holes, they attract more stars, and then you have galaxies. And this takes a while. The idea was that it would take about a billion years for you to have big galaxies.

But in comes the James Webb, and we find that, nope—there were huge galaxies right around the same time that the first stars were being formed. So somehow we have to find a way of increasing the speed at which galaxies form.

So we’re surrounded by mystery.

Absolutely. I wrote a book called *The Island of Knowledge* a few years ago, where I said that the island of knowledge is surrounded by the ocean of the unknown. And as the island grows, so does its periphery, which is the boundary between the known and the unknown. So the paradox of knowledge is that the more you learn, the more you discover that you don’t know.

That sounds like a profoundly depressing realization for a scientist.

If you’re a card-carrying “reason will solve everything and science is truth,” person, then maybe. But in my case, I think it’s inspiring because it means there is no end to the quest; we humans will always have a limited grasp of what reality is. And what could be more fascinating than being surrounded by mystery?

If you’re someone who likes mystery. I think we humans tend to have a contentious relationship with the unknown.

Yeah, you know, in my other life, where I do all these extreme sports like endurance running, we have this saying—“you have to get comfortable with being uncomfortable.” I think that applies here too—you have to be

The paradox of knowledge is that the more you learn, the more you discover that you don't know.

comfortable with the fact that we will never know everything, that there are questions that have no answers, and that's not a bad thing.

As a theoretical physicist, you've been working with big questions and mysteries for most of your career, but what drew you in that direction to begin with? I know your mother died when you were very young. Do you think that helped shape you as someone who was drawn to those questions?

Yes, absolutely, I have no doubt about that. I was 6 when my mother died, and it was a time of darkness in my life. There was just this void, the emotional void of not having a mom, you know? All your friends have moms, who come and pick them up from school and hold their hands. My dad sometimes came by, but he was a busy man. So what do you do with that kind of loss?

Did you have any kind of faith tradition to help explain it?

My family is Jewish—and I had a pretty traditional Jewish education—with traditions, but not so much belief in all of the details of the Old Testament. But there's an element of the supernatural in all the big monotheistic religions, and I tried to connect with that. I was obsessed by supernatural stories and supernatural beings. When I was about 11 years old, vampires in particular were fascinating to me because they were both

living and non-living, they had a foot in the world of the dead and a foot in the world of the living. So I said, "Hey, maybe if I became a vampire, I could go and connect with my mom!"

And you were growing up in Rio de Janeiro, which must have been filled with stories of the supernatural?

Oh, big time. There were spirits everywhere, according to my nannies. My dad was superstitious, too. Every Monday was Souls' Day, so people would go to the crossroads and light up candles and leave offerings for the spirits. Yeah, in Rio, you can't avoid the other dimension.

Did you ever feel like you were able to be in touch with your mother?

Many times. In fact, if you had asked me when I was 9, I would have sworn that I could see her sometimes hovering in the big, long corridor of my house. I was desperate for that connection.

But then I started to transition from that to nature and to being in the natural world by myself. That's when I began to fish. I was 12, and I would go all by myself to Copacabana Beach and spend hours alone fishing. I mean, what kid does that? I was surrounded by all these retired men, who were always like, "what is this kid doing here?" And I was just there, hanging out, looking at the horizon for two or three hours, you

You have to get comfortable with being uncomfortable.

know, three or four times a week. For years, I did that. It was really trying to connect with, I don't know what, the vagueness of the horizon? Because it is a weird place, the horizon, when you think about it—where the earth and the heavens join. The line of connection between one world—ours—and another world, which is up there.

I can see you feeling drawn to that—as though you yourself, in your life, were hovering there, stuck on the horizon in a way, because your mother's death propelled you into this in-between place?

Exactly. And then I discovered Einstein. And that changed everything because I realized that some of these questions about space, about time, about duration, about the origins of everything, were actually also scientific questions.

How do you go from being a boy who thinks maybe he could see his mother's ghost and who believes in spirits, to being a scientist working in the materialist paradigm?

Well you can see that I didn't choose to work on superconductors or lasers or bacteria! I chose to work on the nature of space and time and the Big Bang and the origin of life. These are really boundary questions

between scientific and philosophical or religious thinking. So I think I found a way to be what you could possibly call a rational mystic.

Did that ever create problems for you in the scientific community, among other scientists?

No, simply because I never told them. Like—and I'm not comparing myself to Einstein—but I'm sure that Einstein also didn't talk about his Spinoza notion that God is everywhere.

That's what he thought?

He had a very wonderful—and I would say mystical—way of relating to this intelligence that he found embedded in nature, which was some sort of divine presence. He didn't associate it with a Jewish God or anything like that, but there was something and he thought that science was a portal to connecting with this kind of intelligence.

That's way more mystical than I thought Einstein was. I mean, there's his famous remark, "God does not play dice with the universe."

Yeah, but that was a joke. He had a much deeper connection, what I would call truly a mystic connection to the natural world, and to this kind of hidden

intelligence in the depths of nature that we can never quite understand, but which is there. He has this famous quote that I love, which is: “the most beautiful experience we can have is the mysterious.” I mean, who would write that? Krishnamurti, yes—but that was Einstein!

So we’re circling around the subject of storytelling. Lately you’ve been saying that we need a new story of the universe, that ever since Copernicus, science has been telling the story of cosmological history wrong. That’s a pretty big rewrite.

I’m saying we have to rethink the story of who we are and how we relate to the planet. A little bit of deep time history here: *Homo sapiens* have been here on this planet 300,000 years, more or less. Of that time, about 95 percent, almost all of it, we were hunter gatherers moving about the planet. And we had a completely different relationship to the world than the agrarian civilizations did. For the hunter gatherers, the world was sacred. They understood that there were powers in nature that were beyond themselves, that they were not above nature.

But that was 10,000 years ago, so how do we know? Are you extrapolating from what current Indigenous cultures and traditions have to say?

No, we have anthropological evidence of how earlier hunter gatherers congregated and how and what they ate. It’s amazing that we can tell that story. And of course, there is a dark side, and maybe overhunting was what caused the extinction of the mastodon and other mammals. But yes, I think current Indigenous cultures carry that tradition of coexisting with the natural world and respecting the sacredness of a place. Agrarian societies ushered in a complete phase transition: “look, we can actually control nature. We can tame the plants and animals to serve our purposes, and we can be the masters of the world.” No wonder the monotheistic religions say God created the world for humans.

And suddenly we get stories of paradise. Gardens of Eden given to us.

And most importantly, look what happened to the gods. Once, they were part of the trees, the rivers, the

waterfalls, the winds, the volcanoes. Now, the gods are way up there, far away from the world. The world is not divine anymore. It becomes an object.

And this is the precursor to the revolutionary moment when Copernicus says Earth is also not the center of the universe?

Right. And then when Copernicus says, “Look, the Earth is not even the center of everything, the sun is,” then the Earth became not the center of creation, but just another world. Which further disrupted the vertical hierarchy of us here on Earth and the gods up in the skies. Now that Earth is revolving around the sun, it becomes less important. And we become less important too, because immediately after Copernicus, people started to speculate: “Wait a second. If there are other worlds, why should life only be here?”

Really, right afterward?

Very, very quickly. Copernicus published his book in 1543. In the 1580s, Giordano Bruno was saying, look, the stars are just like the sun, so they should also have planets moving around them, and those planets should have life, just like here. In the early 1600s, Johannes Kepler, who came up with the mathematical laws of planetary motion, wrote a fictional story about a trip to the moon.

So people were already beginning to think about escaping the Earth and heading to other planets.

It was all over the place. In 1686, one year before Newton published his famous book that changed the world, a French philosopher, Bernard le Bovier de Fontenelle, published a book called *Conversations on the Plurality of Worlds*. And then as science advanced, we learned more about stars and galaxies and the expansion of the universe. But within the framework of the Copernican narrative, the more we learned about the universe, the less important we and this planet became.

And today we talk about multiverses.

Yeah, that’s the final insult, right? “Hey, there’s not just our universe, there are countless universes! Ours is just one.”

There’s this thing people talk about in astronomy, the principle of mediocrity—meaning we are not important at all. I think this is just completely wrong.

We carry the whole history of the universe in ourselves.

Because there is a fundamental element missing in this whole story: We have no clue what life is or how it emerged on this planet. I mean, we don't even know how to define life very well. We have an operational definition: a biochemical network system that is capable of metabolism and of Darwinian evolution. But that's what life *does*—it doesn't tell me anything about what life *is*.

In the meantime, there's a lot of money going into looking for exoplanets that might support life. Elon Musk thinks we can terraform Mars. There's the whole narrative of "when we've wrecked this planet, we'll head to another." You're pushing back on all that?

Okay, let's qualify. Searching for other planets, and in particular searching for biosignatures, meaning the signs of life, is essential research right now. I work on this. But Elon Musk and terraforming Mars? That's just silly stuff. Our problem right now is the next few decades on this planet—not if, in 500 years, we're going to have a colony on Mars. I mean, that's useless.

Then why even bother looking for exoplanets? Why not focus our attention on this one?

Because that's how we advance knowledge, by asking profound questions about the universe and matter. Looking for life on other planets is essential because for now, as far as we know, Earth is the only planet that has life. The post-Copernican narrative decreased the value

of our world, and we constructed a whole civilization based on the idea that we can use and abuse it. We built giant cities and industries by essentially consuming the entrails of our planet. Oil, gas, and coal—the insides of the planet—fed our technologies, and it all worked until it didn't.

At this point, it almost seems like the problems are too big to do anything about.

So what can we do? Well, we can tell a different story. First of all, when you look at the evolution of life, you realize that it's completely dependent on the history of the planet. If you change or tweak something that happened here on our planet a long time ago, life would be different, which means we wouldn't be here.

The most famous example is 66 million years ago, the big asteroid hits the Yucatan Peninsula. It wipes out the dinosaurs and a bunch of other creatures, with the exception, maybe, of the birds and some little mammals. It completely changed the evolution of life on the planet. And it was a cosmic accident.

So your point is, it's not about counting up the number of planets that could possibly support life because they've got the right chemistry and the right mass. It's that there were so many little contingencies without

which you could never get this form of life again. Although, you might get a better one.

What I'm trying to say is that instead of thinking of the Earth as just another planet and life as ubiquitous in the universe, the truth is that Earth is not just another planet. The Earth is a very rare oasis that has supported life for at least three and a half billion years, which allowed for life to change and adapt to different environments that coincidentally and completely randomly evolved to generate a species that is able to reconstruct this entire story and to tell it. And without our voice, the universe itself would have no story, would have no memory. It would be a dead universe. So it's not just that we are stardust, as Carl Sagan used to say—we are how the universe is telling its own story.

I think this is only possible because of this incredibly spectacular and rare planet that we live on. Look at Mars, a horrible frozen desert. Look at Venus, a boiling soup of sulfuric acid. Other planets, you can't even stand on them because they're gas giants. So this is not just another world; it's a rare gem in the universe. And yes, there could be other planets with life on them, maybe. But probably very simple life—single-celled organisms. Never or very rarely complex organisms.

The other thing I was thinking about is James Lovelock's Gaia Theory and the suggestion that at some point the universe would develop consciousness. It sounds like you're saying it already has—in the form of humans.

That's the beauty of this whole story. We carry the whole history of the universe in ourselves. The atoms in your body—the iron in your blood, the calcium in your bones—came from stars that exploded 5 billion years ago. They traveled gazillions of light-years to fall four and a half billion years ago into this nebula that was collapsing to become the sun and the planets. And then in one of these planets, which happens to have water and carbon and magnesium and phosphorus, molecules organized themselves and became alive—and then began to evolve, three and a half billion years ago, into a species that is telling this story. That is not something that is going to be happening all over the universe!

The Buddhist monk Thich Nhat Hanh has a beautiful concept called “interbeing,” which he described this way. He said: Let's say you're reading a poem, and the

poem is printed on a sheet of paper. Well, that paper came from a tree. The tree only grew because there is water and there is sunlight. But the sun is a star, and the star is shining because there is a universe that developed stars. So every time you look at a piece of paper, you are connected to the rest of the universe.

And that's what I'm talking about: the re-sacralization of the planet.

Do you think doing science can be sacred?

Absolutely. Not everybody will agree with me, but that's how I wake up every day—to go do my calculations and write my papers and try to figure out if there is life on another planet. To me, that's a sacred engagement with the universe. And I know I'm in very good company saying that, because Einstein used to say the same thing. ☺

ANNE STRAINCHAMPS is the host of *To The Best Of Our Knowledge*. She co-founded the show, along with Steve Paulson and Jim Fleming, and has been a featured interviewer on the program for more than a decade.



Yes, We Have Free Will. No, We Absolutely Do Not

*A volley of new insights reignites the debate over whether our choices
are ever truly our own*

BY DAN FALK





YOU'RE THIRSTY SO YOU REACH FOR a glass of water. It's either a freely chosen action or the inevitable result of the laws of nature, depending on who you ask. Do we have free will? The question is ancient—and vexing. Everyone seems to have pondered it, and many seem quite certain of the answer, which is typically either “yes” or “absolutely not.”

One scientist in the “absolutely not” camp is Robert Sapolsky. In his new book, *Determined: A Science of Life Without Free Will*, the primatologist and Stanford professor of neurology spells out why we can't possibly have free will. Why do we behave one way and not another? Why do we choose Brand A over Brand B, or vote for Candidate X over Candidate Y? Not because we have free will, but because every act and thought are the product of “cumulative biological and environmental luck.”

Sapolsky tells readers that the “biology over which you had no control, interacting with the environment over which you had no control, made you you.” That is to say, “everything in your childhood, starting with how you were mothered within minutes of birth, was influenced by culture, which means as well by the centuries of ecological factors that influenced what kind of culture your ancestors invented, and by the evolutionary pressures that molded the species you belong to.”

Sapolsky brings the same combination of earthy directness and literary flourish that marked his earlier books, including *Why Zebras Don't Get Ulcers*, about the biology of stress, to this latest work. To summarize his point of view in *Determined*, he writes, “Or as Maria sings in *The Sound of Music*, ‘Nothing comes from nothing, nothing ever could.’”

The affable, bushy-bearded Sapolsky is now in his mid 60s. During our recent interview over Zoom, I was on the lookout for any inconsistency; anything that might suggest that deep down he admits we really do make decisions, as many of us surely feel. But he was prepared and stuck to his guns.

I had no issue with the first part of his argument—that cultural, genetic, and environmental factors

influence our lives, and nudge us in certain directions. But how could those factors dictate what we say or do in each moment? He turned the question back on me.

“Why do you value that question?” he said. “Why did you wind up being a person who would be interviewing somebody about this subject? That wouldn't have happened, for instance, if you had been raised with intestinal parasites in the middle of Niger.”

To most people, Sapolsky said, free will is apparent in real time, for every action you perform. “You ask, ‘Did you intend to do it? Did you realize you could have done something else? That you had options?’ Most people's intuitive sense is the answers are yes, and so you have demonstrated free will. But that's like trying to evaluate a movie by only seeing the last three minutes of it. When you ask, ‘Where did intent come from?’, everything from one second to a million years before comes into play. That leads inevitably to the conclusion that there's no free will. Because no matter how much you try, you can't intend to intend something. You can't will yourself to have willpower. You can't think of what you're going to think of next. It's simply not possible.”

The way Sapolsky sees it, you can't escape the biological and cultural forces and environmental factors that preceded you and shaped you. “There's not a crack anywhere in there to shoehorn in free will,” he said. “When you look at every contemporary argument for free will that's not invoking God or fairy dust or something, at some point, one must assume a step that bypasses the antecedent causes. But that violates the laws of how neurons work, atoms work, and universes work. Your life is nothing but that: everything that came before.”

Your life is nothing but that: everything that came before.

MANY SCIENTISTS AND PHILOSOPHERS beg to differ. Prominent among them is Kevin Mitchell, a neuroscientist at Trinity College in Dublin. In his new book, *Free Agents: How Evolution Gave Us Free Will*, Mitchell argues that although we're shaped by our biology, it's that very biology that made us, over the course of billions of years of evolution, into free agents. Even the earliest and most primitive creatures had some capacity to control their destinies. When a single-celled organism moves toward a food source, or away from danger, it has entered, however meekly, into a new world of agency and freedom. Simple organisms, Mitchell writes, "infer what is out in the world" and "make holistic decisions to adapt their internal dynamics and select appropriate actions." He adds: "This represents a wholly different type of causation from anything seen before in the universe."

A dozen years younger than Sapolsky, and with a less voluminous beard, Mitchell was born near Philadelphia but grew up in Ireland; he then returned to the United States for grad school and a postdoc, before heading back to Dublin. That accounts for his "all over the place" accent, he told me.

In a universe where the mindless laws of nature push bits of matter around, it might indeed seem miraculous that free will—agency—can emerge. As I made my way through *Free Agents*, I thought of a *New Yorker* cartoon where two scientists are at a blackboard filled with equations. In the middle, instead of an equation, the first scientist has written, "Then a miracle occurs." The second guy says to him, "I think you should be more explicit here in step two."

But emerge it does, according to Mitchell, and he's adamant that there is nothing miraculous about it. Rather, in living creatures like us, freedom is enabled by the underlying biology.

But couldn't biology itself be beyond our control? In their books, both Sapolsky and Mitchell refer to the work of neuroscientist Benjamin Libet. In the 1980s, Libet conducted a series of experiments that appeared to



This represents a wholly different type of causation.

show that electrical activity in the brain could be detected several hundred milliseconds before the subject became aware of making a decision—suggesting, to some, that the brain itself must be doing the “deciding,” with the conscious mind following along after the fact. Libet’s experiments were, and remain, controversial; even so, they left many people wondering if free will must be an illusion.

Mitchell doesn’t buy it. Yes, there are physical and chemical processes operating within the brain—how could there not be?—but that does nothing to take away our freedom, he says. “It comes down to the idea that if we can find the machinery inside the brain that is active when we’re making a decision, then maybe decision-making is being done causally by that machinery,” he told me. “I don’t think that view is right, because I think you can have a completely different view, which is, yes, there is some machinery that we use to make decisions; but it’s machinery *we use* to make decisions. *We’re* making the decisions.”

For Mitchell, decision-making did not start with human beings. Rather, it can be traced back to the first simple organisms that flourished hundreds of millions or even billions of years ago. “I wanted to take an evolutionary approach to this problem,” he said.

Evolution, Mitchell said, favors organisms that have some ability to make their way in the world. “They need to know what’s out in the world, and what to do about it.” Creatures evolved the ability to sense, and the ability to act, based on those sensations. They were evaluating (in some primitive manner) which action was likely to prolong their survival. “Even bacteria do this,” Mitchell said. Humans merely do this in a more sophisticated manner.

“We see what’s out in the world, gauge our internal state—bacteria do that too—and, given those things, given my beliefs about the world, and my own state at the moment, and my goals, we ask, ‘What should I do? What’s my range of options? How can I choose one of them and inhibit all the others?’”

Over the course of evolution, creatures with more sophisticated decision-making abilities appeared. “Those capacities got more elaborate, and more sophisticated, which led to organisms with greater and greater agency, with more control,” Mitchell said. “They have a greater range of possible actions; they have more flexible behavior.”

As creatures evolved more sophisticated ways to respond to their environments, they began to plan over longer timescales. “They have a cognitive horizon that gets broader and broader through evolution,” Mitchell said.

“And that means that they have greater causal autonomy. They’re not pushed around by every immediate thing in the environment. They can think about things that haven’t happened yet. And they can direct their actions toward things in the future, sometimes, for us, decades in the future.”

No magic, no miracles—just a capacity for decision making passed down to us over the eons from much simpler creatures, thanks to natural selection.

WHAT’S FASCINATING is Sapolsky and Mitchell have dived into essentially the same scientific and philosophical literature about free will and yet surfaced with opposing conclusions. Can one be declared more right than the other?

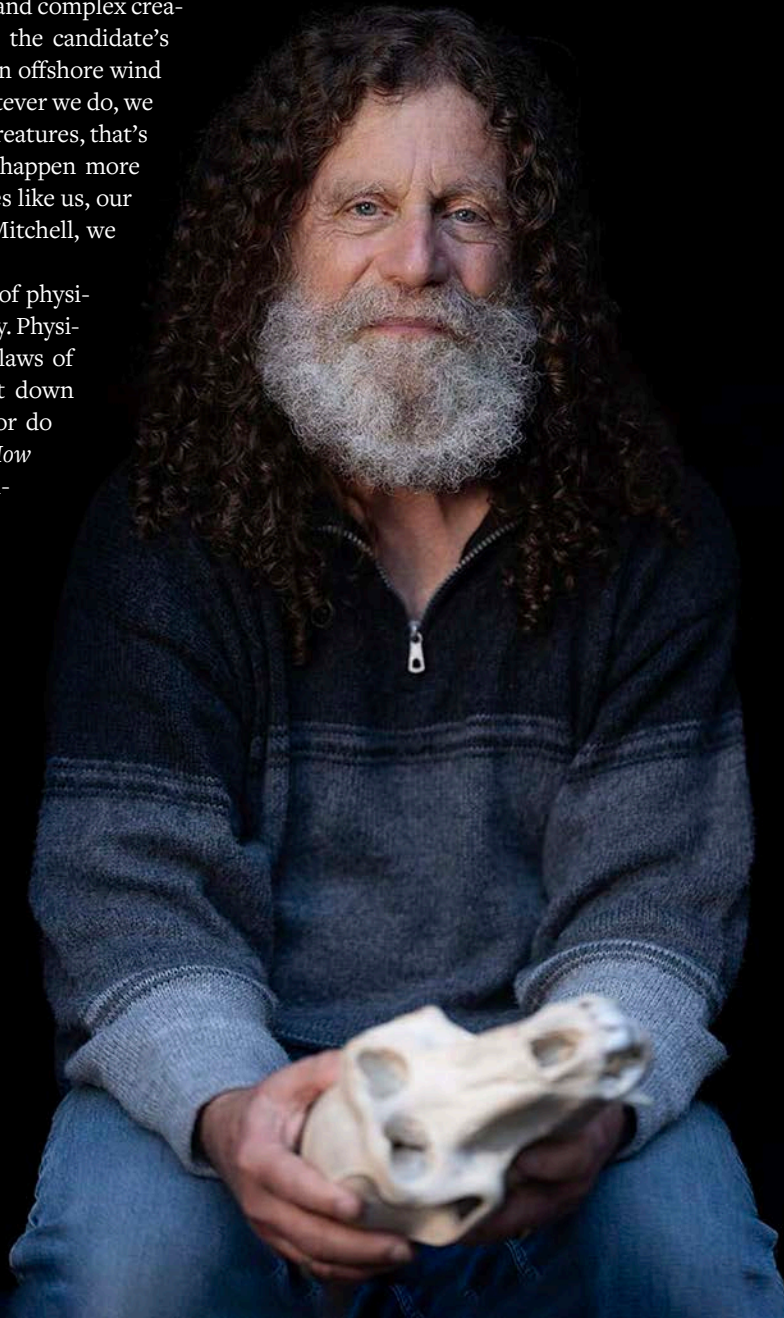
To my mind, Mitchell seems to be on the right track. We really do make decisions, and that ability to make decisions has evolved over the eons. Simple creatures make simple decisions (“a possible food source—must move in that direction!”) and complex creatures make complex decisions (“I don’t like the candidate’s flat-tax proposal, but I like where he stands on offshore wind energy”). A determinist might insist that whatever we do, we do because of what came before. For simple creatures, that’s a fair position. A paramecium’s “decisions” happen more or less on autopilot. But for complex creatures like us, our actions depend on conscious decisions; for Mitchell, we are in the driver’s seat.

Mitchell’s view finds support in the work of physicist Jenann Ismael of Johns Hopkins University. Physicists, of course, have long debated how the laws of nature work, and whether those laws, right down to the behavior of elementary particles, do or do not allow for free will. In her 2016 book, *How Physics Makes Us Free*, Ismael lays out a position broadly aligned with Mitchell’s. Yes, the past paves the way for the present, which in turn shapes the future—but humans are not mere bystanders in this process. “It’s *me* that gets to decide, in the here and now, how the past bears on the future,” she told me in an interview.

Ismael agrees that we are influenced by what has come before—but as she sees it, those experiences inform rather than constrain our decisions. “From the noisy accidents of my life, I’ve extracted hopes, dreams, priorities, and visions,” she said. “When I’m deciding what to do, I sort through those things and make decisions about which of those get to bear on the future.”

NO, WE DON’T

Robert Sapolsky on free will: “I have spent forever trying to understand where behavior comes from. And what you see is there’s absolutely no room for free will.”



And yet some of Sapolsky's arguments are also convincing. He, too, has physicists on his side. In her 2022 book *Existential Physics*, physicist Sabine Hossenfelder writes that the idea of free will is incoherent. "For your will to be free, it shouldn't be caused by anything else. But if it wasn't caused by anything—if it's an 'uncaused cause,' as Friedrich Nietzsche put it—then it wasn't caused by you, regardless of just what you mean by you. As Nietzsche summed it up, it's 'the best self-contradiction that has been conceived so far.' I'm with Nietzsche."

For Sapolsky, recognizing that individuals are shaped by their past offers a blueprint for a more just society. Sapolsky believes we shouldn't praise people for accomplishments they achieved largely because of a string of advantages that helped them throughout their lives; and he argues—correctly, I would say—that it's wrong to condemn those who are struggling, merely because of the many disadvantages they have faced.

Consider a neurosurgeon and a criminal. The neurosurgeon "is not a better human because circumstances produced someone with the capacity to be a competent neurosurgeon," Sapolsky told me. "And the other person is not a worse human because circumstances produced someone who is going to be violently impulsive in certain circumstances."

At the same time, I can't help wondering: If individuals don't have the freedom to choose, how can courts or legislatures or whole societies have it? If freedom is an illusion, it might seem that an idea like "advocating for judicial reform" is rendered meaningless, too. How can one do *anything* other than what we're supposedly determined to do? In Sapolsky's view, although we can't change the world, we can *be changed* by the world.

"Things change enormously!" Sapolsky said. "We don't keep slaves anymore. We put on a sweater today because it's cooler than it was yesterday. Someone who used to be a white supremacist now regrets it and works for tolerance. We get gummed up thinking we're seeing free will. We have this incorrect belief that we have chosen to change ourselves. The white supremacist didn't wake up one day and say, 'Hey, it's about time I stopped being a white supremacist.' He was changed by circumstances."

So how did these two very clever scholars end up with such different views? I think the answer is they targeted different facets of the free will puzzle. Sapolsky is worried we overestimate how much freedom we have by failing to take into account the biological, sociological, and environmental forces that have made us who we are. And he's right: We *should* take those forces into account.

YES, WE DO Kevin Mitchell on free will: "We really are free agents. We make decisions, we choose, we act—we are causal forces in the universe."



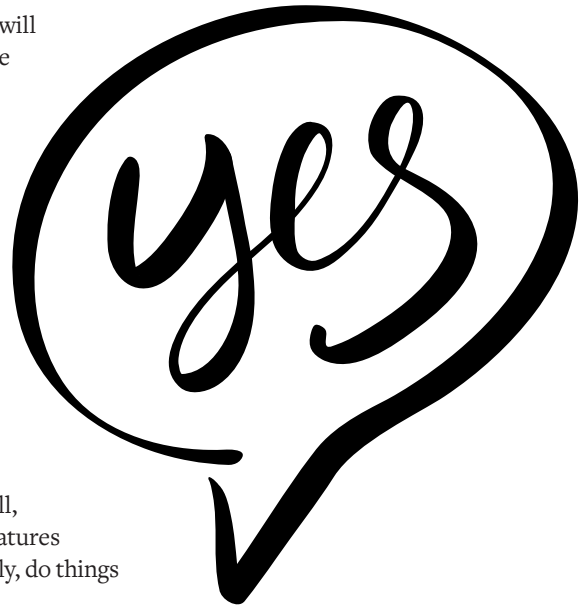
But he may have pushed the argument to the extreme, imagining that these restrictions on free will leave no room for any freedom at all. Sure, the fact that my dad loved playing folk songs on the piano when I was growing up probably increased the odds that I'd enjoy "Hey Jude" as an adult—but did my past really dictate, down to the second, when I might reach for that glass of water?

Mitchell, meanwhile, is focused on "rescuing" free will from a seemingly deterministic universe. This rescue operation (which gets bogged down in physics) is not necessary; philosophers have long argued that we can have the sort of freedom that matters regardless of what our atoms and molecules are doing. At the end of the day, one can't pick a winner between Sapolsky and Mitchell any more than we can pick a winner between the New York Mets and the New York Rangers—they're not playing the same game.

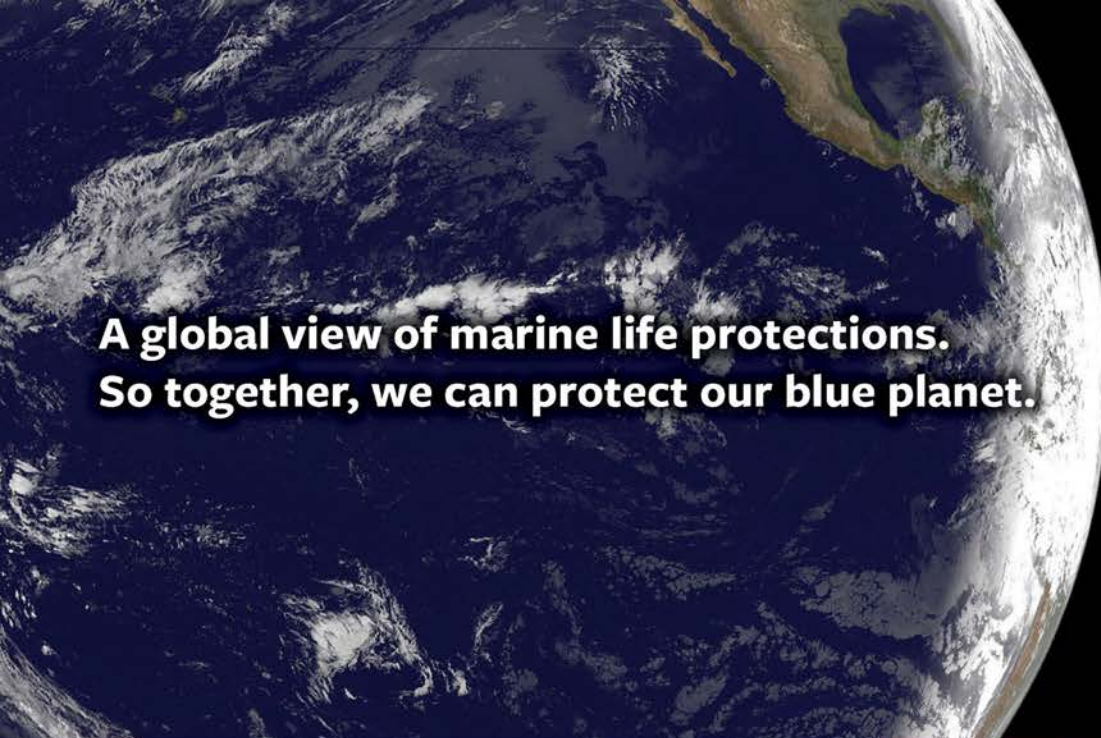
Even though Sapolsky and Mitchell cover a lot of ground, questions remain. One might wonder how to quantify those biological and cultural forces that anchor Sapolsky's thesis. How might one prove that they allow for no freedom at all? And for Mitchell, who struggles to reconcile the workings of complex creatures such as humans with the underlying physics: How, exactly, do things like minds and agency arise from inanimate matter?

These two books show just how wide the problem of free will is. And because the problem can be approached in so many ways, we can be sure it's not going away anytime soon. As Ismael told a lecture audience in Toronto recently, the puzzle of free will is the ultimate philosophical whack-a-mole.

"When you tease out one thread of argument that's supposed to lead to the conclusion that there is no free will ... people say 'No, no, that's not what I meant by free will,' or, 'the problem's not over there, it's over here,'" she told me. "And they give you a different argument, or they give you a different conception of free will. So every time you nail down one of them, you get something else coming up where people say, 'no, no, the real argument is over here.'" 🌀



DAN FALK (@danfalk) is a science journalist and broadcaster based in Toronto. His books include *The Science of Shakespeare* and *In Search of Time*.



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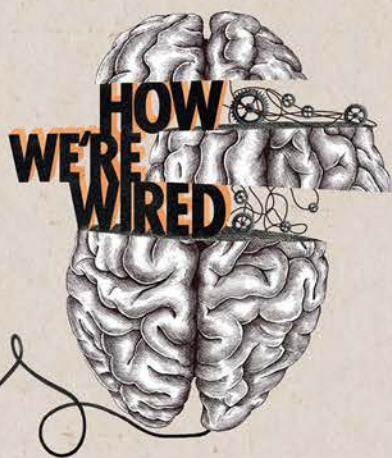
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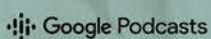
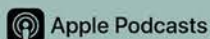
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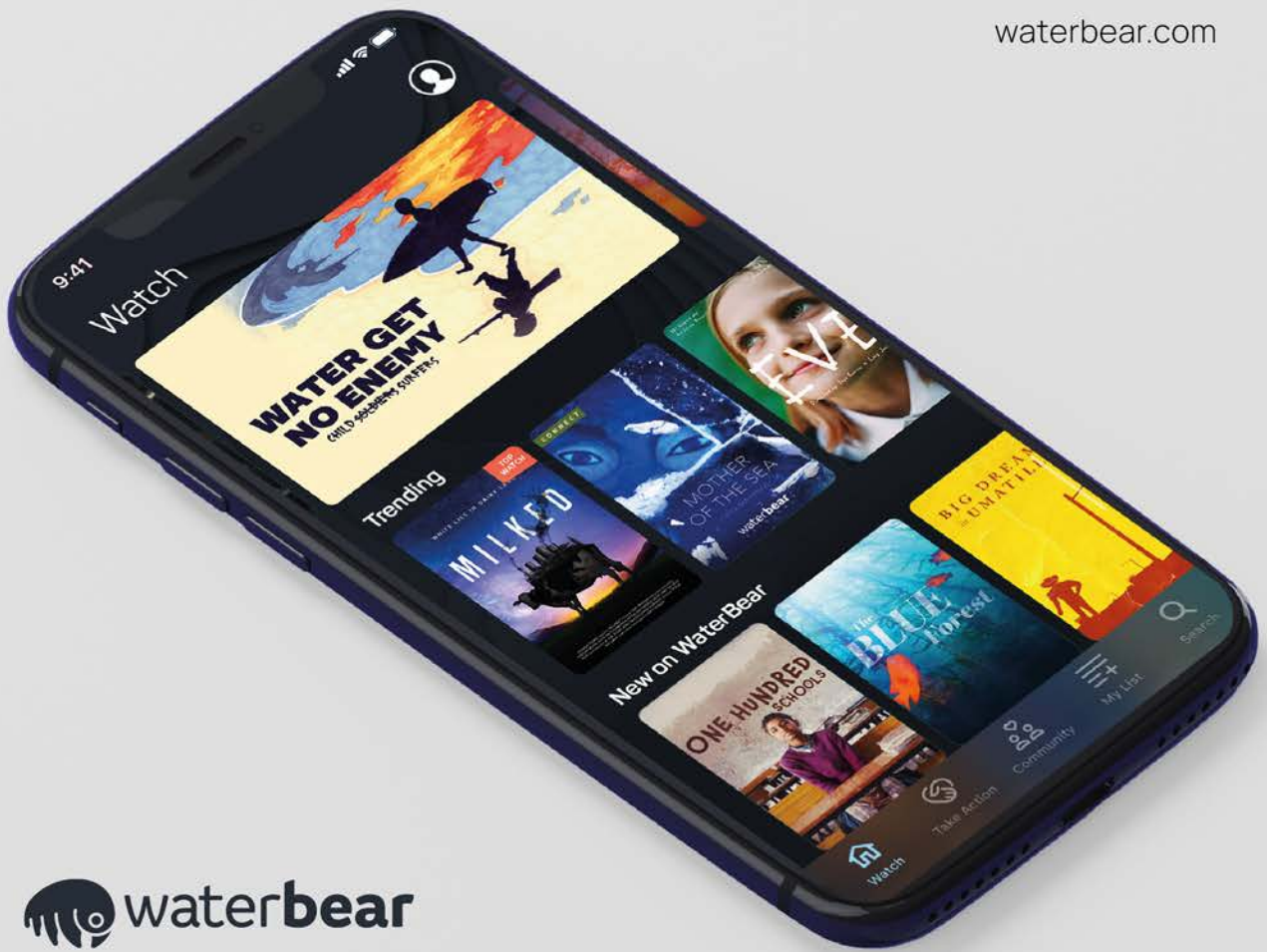
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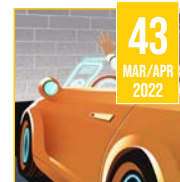
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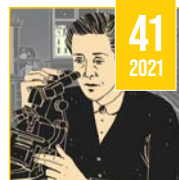
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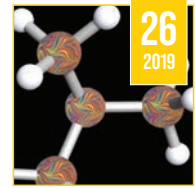
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Joseph LeDoux

The neuroscientist on his new theory of being human

NEW FUNCTIONS EVOLVE FROM OLD

For me, writing is a process of discovery. For example, when I began my latest book, *The Four Realms of Existence: A New Theory of Being Human*, I assumed—like many neuroscientists—that the nervous system consists of two distinct functional units: the central nervous system and the peripheral nervous system. But while researching the book, I came across a paper from the 1970s by Alfred Sherwood Romer, a prominent paleontologist, who was interested in the evolution of the nervous system. It rocked my world.

Romer pointed out that each animal, including the human, is an imperfect union between “two somewhat distinct beings”: a “somatic” animal—flesh and bone—and a “visceral” animal—the digestive tract and its appendages. Romer, in effect, endorsed an organizational chart of the nervous system that flips the traditional one on its head. He made the somatic and visceral nervous systems the major partition, with the central and peripheral neural tissues secondary.

His perspective opened my mind to a fundamental tenet of evolutionary theory—that new functions evolve from old. This helped me understand how the neurobiological realm evolved out of the biological realm, but also how the cognitive realm evolved from the neurobiological and the conscious realm from the cognitive. This became the framework for my book: I proposed that a nested hierarchy defines the four realms of existence.

WARM BLOOD MAKES MAMMALS SMARTER

You have probably heard about the impressive cognitive capacities of birds, especially parrots and corvids.

Their cognitive capacities are said to rival those of primates. But why did evolution single out mammals and birds for higher cognition? It turns out only mammals and birds are warm-blooded. To maintain their

higher body temperature, they have to burn more calories, which means they have to move around more and consume more food than cold-blooded creatures, such as reptiles. Advantages might therefore accrue to organisms that could use cognitive abilities, especially the ability to construct internal mental models of the world and use them to make plans about when and where to forage, and what kind of food to seek, in relation to predictions about energy needs. Birds and mammals very likely evolved these similar capacities separately, as a solution to distinct selective pressures they faced.

THE CONSCIOUS AND PRE-CONSCIOUS ARE HARD TO TELL APART

Both speech and writing are often based on unconscious cognitive processes. Think about it. In conversation you frequently do not plan what you are saying, you just say it, and when writing you often just write away. Underlying these activities are mental models that integrate present stimuli with memory to achieve a momentary goal. You observe what you say or do as it is happening and build that into a simultaneous conscious mental model. These ideas, which came to me while writing the book, became the foundation for a dual mental model framework. The main idea is that one cognitive mental model is pre-conscious, which, in turn, spawns a conscious mental model. Both models can control speech and action. If I am correct, the effort to scientifically understand and experiment on consciousness may be even more complicated than we thought, because it is very difficult to determine, at any given moment, whether a given act of speech or behavior is controlled by a pre-conscious or conscious mental model. ☺



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