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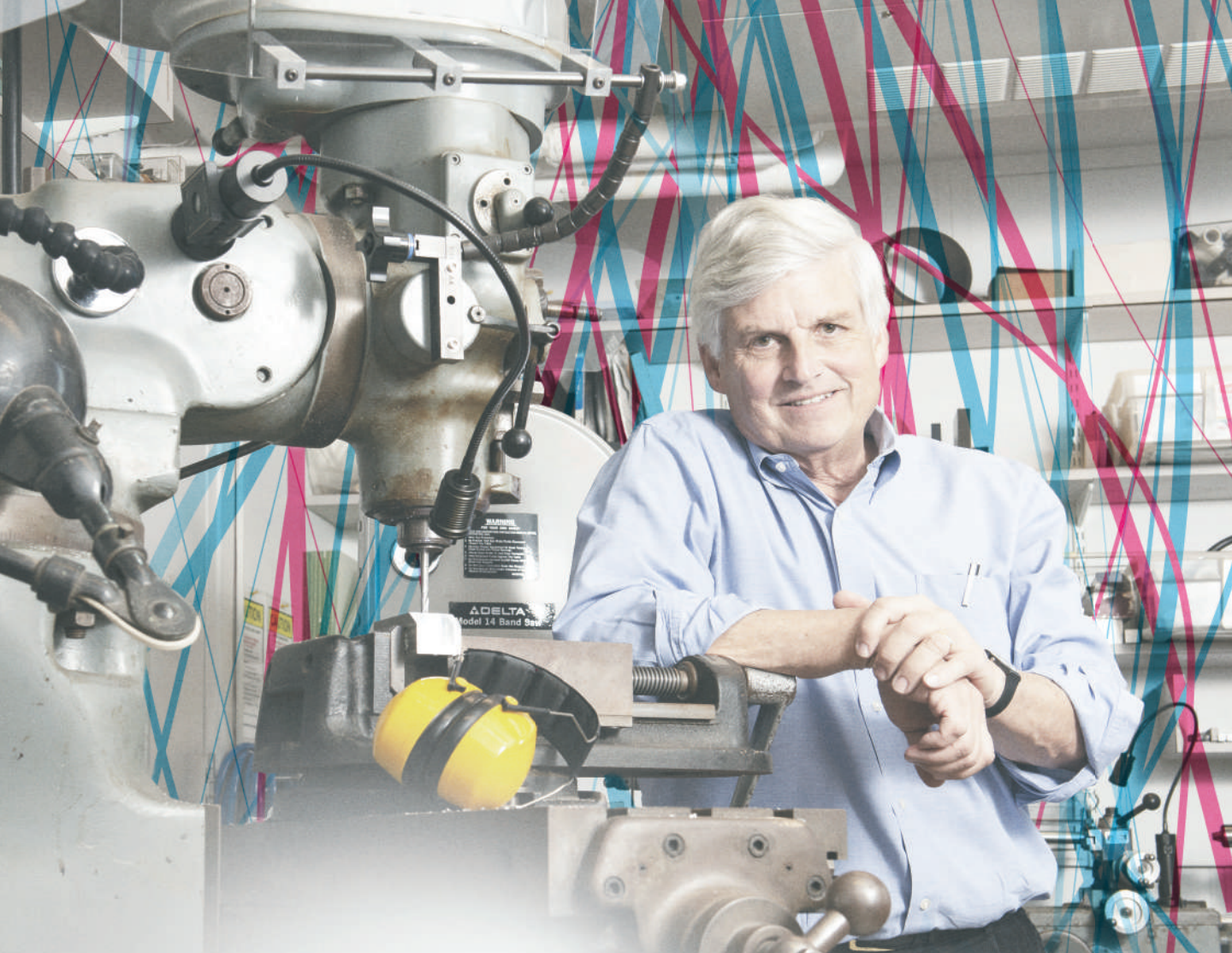
A BOLD THEORY OF TIME

Breaking one of physics' oldest laws



The Physicist and His Analyst

WHEN WOLFGANG PAULI AND CARL JUNG SAW EYE TO EYE P.20



David P. Corey is the Bertarelli Professor of Translational Medical Science in the Department of **Neurobiology** at Harvard Medical School, where he also co-directs the Center for Hereditary Deafness. His laboratory works both on elucidating the molecular composition of the mechanotransduction complex in auditory receptor cells, and on developing transformative new viral vectors for gene therapy for the inner ear.

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Contents

Editor's Note

- 5 *Enchanted Science*
BY KEVIN BERGER

Reader Response

- 7 *Comments and letters about stories from print issue 34*

Preludes

- 12 *How chess changes our brains; sea turtles' navigation systems; why we judge people when we meet their families; how to farm in cities; and the beauty of symmetry in nature*

Cover Story

PHYSICS

- 20 The Synchronicity of
Wolfgang Pauli and Carl Jung
How the theoretical physicist and analyst came together and then apart
BY PAUL HALPERN

The Last Word

- 108 Daniel Levitin
*The neuroscientist and author of *Successful Aging on outwitting the Grim Reaper**
INTERVIEW BY KEVIN BERGER

COVER Jorge Colombo





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Features

- PHYSICS
- 30 **A Supermassive Lens on the Constants of Nature**
What this year's Nobel-winning discovery of the black hole at our galaxy's center reveals
BY SIDNEY PERKOWITZ
- HISTORY
- 36 **Do You Know These Scientific Pioneers?**
10 great minds that should have been in your science textbooks
BY TOM SIEGFRIED
- HISTORY
- 40 **When Science Was the Best Show in America**
The first US museum was devoted to truth and reason. Then the circus came to town.
BY LEE ALAN DUGATKIN
- ANIMALS
- 46 **Lessons for the Return of Great White Sharks**
Modern science has largely debunked the idea of sharks as marauding "man eaters." Can modern culture catch up?
BY CLAUDIA GEIB
- TECHNOLOGY
- 56 **Toys Are the Future of Philosophy**
Playthings shouldn't confine kids but allow them to ask, What if?
BY JONATHON KEATS
- HISTORY
- 62 **What Did the Past Smell Like?**
Get a whiff of a new sensory experience in history
BY ANN-SOPHIE BARWICH
- PHILOSOPHY
- 66 **The Joys of Being a Stoic**
Science and ancient Greeks agree—Stoicism increases well-being
BY MASSIMO PIGLIUCCI
- ENVIRONMENT
- 72 **How to Fix the Wildlife Conservation Crisis**
The ongoing COVID-19 pandemic has exposed long-standing weaknesses in how we protect African wilderness and species
BY RACHEL NUWER
- NEUROSCIENCE
- 84 **Reading, That Strange and Uniquely Human Thing**
How we evolved to read is a story of one creative species
BY LYDIA WILSON
- PHYSICS
- 92 **Time Flows Toward Order**
Revisiting the gospel of the second law of thermodynamics
BY JULIAN BARBOUR



NAUTILUS

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NAUTILUS Next

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Enchanted Science

BY KEVIN BERGER

THE “PAST IS PROLOGUE” defines this issue of *Nautilus*. I guess Shakespeare’s line from *The Tempest* always defines science, where the insights of the past light the way to the future. Newton sounded a similar chord when he said of his perceptions into planetary motion, likely referring to the astronomers and philosophers before him, Galileo, Kepler, and Descartes, “If I have seen further it is by standing on the shoulders of giants.”

The history of science is never just history. That’s true for all history. Every path of our lives has been carved by the invisible hands of the past. Which is something you realize as you get older and find yourself behind the wheel of a large automobile, asking, How did I get here? (Now we know why our parents were always reading books like *A Distant Mirror* and *The World Rushed In*.) But, particularly in the case of science, calculations made in gas-lit rooms and Victorian labs, which uncovered how nature ticks, glow in the best current research, which is why it’s so enchanting to read.

This issue is full of enchantments. They begin with our cover story that spotlights the friendship between physicist Wolfgang Pauli and psychologist Carl Jung. Both sought to mine connections in their respective fields, Pauli among the quantum particles, Jung among, well, the cosmos. Jung introduced the term “synchronicity” to describe an underlying order to what he saw as meaningful coincidences. Mystical as it sounds, and is, author Paul Halpern points out that Jung’s fanciful notion parallels with the emerging concept of quantum entanglement.

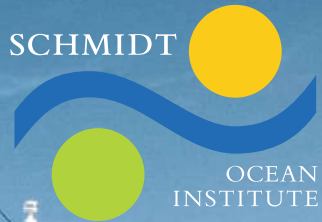
“One of the remarkable aspects of the Pauli–Jung collaboration,” Halpern writes, “was how their rhetoric had begun to converge. Thanks to Pauli, Jung had become far more knowledgeable about quantum physics, including its chance aspects and the role of observers. Thanks to Jung, Pauli had become immersed in the studies of mysticism, numerology, and ancient symbolism.”

The influence of Pauli, who won the Nobel Prize in Physics, and Jung, is incalculable today. The giants of physics, Newton and Einstein, stride through two articles in this issue, “A Super-massive Lens on the Constants of Nature,” about 2020’s Nobel Prize in Physics, awarded for the discovery of a black hole in the center of our galaxy, and “Time Flows Toward Order,” a bold and engaging departure from the doctrine of entropy and the second law of thermodynamics.

The synchronicity of past and present is also exhibited in “When Science Was the Best Show in America,” about the first science museum in the nation and its eventual collapse under pressure from P.T. Barnum. “National funding for truth and reason foundered on the shore of politics,” writes a sly Lee Alan Dugatkin. “And then the circus came to town.”

This issue, though, is not a history lesson. It’s also defined by two deeply reported stories about wildlife in danger. The stories show that scientific methods can help save the world’s wildlands and animals and do something more: Revive our enchantment with nature and inspire us to save it ourselves.

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Readers Respond

Comments and letters about stories from print issue 34.

“THE FLEXIBLE CITY”

It is only a matter of time. The line in the article that we may never have self-driving capability reminds me of those who said we would never fly or go to the moon—short-sighted. However, I applaud the author for this different vision of what the future may bring and admitting that we are never 100 percent certain of what the future holds. Interesting read overall.

—MN in FL

All human drivers, fine. All fully self-driving cars, fine. The mix, not fine. I agree with you but I think you need to give over whole towns to self-driving cars and avoid the mix which comes with making only new cars self-driving. Most of my time driving in London is spent negotiating with other car drivers. Because the roads are too narrow to have parked cars on both side and two driving lanes, drivers share the middle of the road in ongoing subtle negotiations which robots just wouldn't be able to do with humans.

—disqus_tmYlDEj1DL

“THE FUNGAL EVANGELIST WHO WOULD SAVE THE BEES”

Stamets and Sheldrake are two of the most influential people in the effort to place fungal life in perspective for humans. Consider that there would be no terrestrial life on this planet without the mycological

kingdom. When humans have finally been done with destroying the ecology of this planet it will be fungus that begins the rebuilding.

—brian

“THE PHYSICIST’S NEW BOOK OF LIFE”

Despite the suggestion that religious ideas can be informative in the “What is life?” question this is another attempt to explain life within the standard materialist paradigm. And it entirely leaves out consciousness, which is the most striking feature of life. No explanation of life or physical reality can be adequate without including an explanation or role for consciousness.

—Steven Harp

“ARE WE WIRED TO BE OUTSIDE?”

Thanks for the interesting journey into the latest neurological studies, and the delightful hike. One of my pet theories about the impact of broad natural landscapes—mountains, oceans, forests—on the human brain is that the granularity of these visual images extends beyond the capacity of the visual cortex. Our eyes and brains are incapable of distinguishing the individual details, which both frustrates and stimulates our efforts to “make sense of it all.” We are confronted with something that appears to be infinite—beyond comprehension. So, yes, this would depress the

alpha, and might correspondingly increase the deeper brain waves, triggering for many a sense of deep emotional or spiritual connection.

—George Gantz



Nautilus welcomes reader responses.

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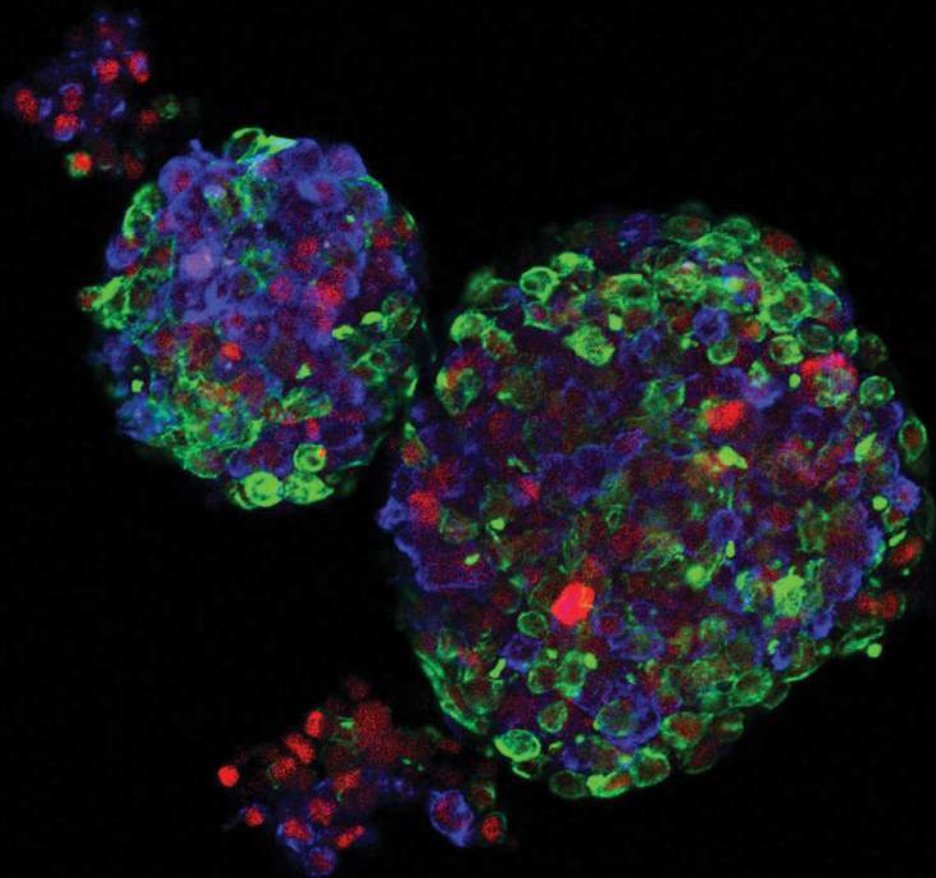
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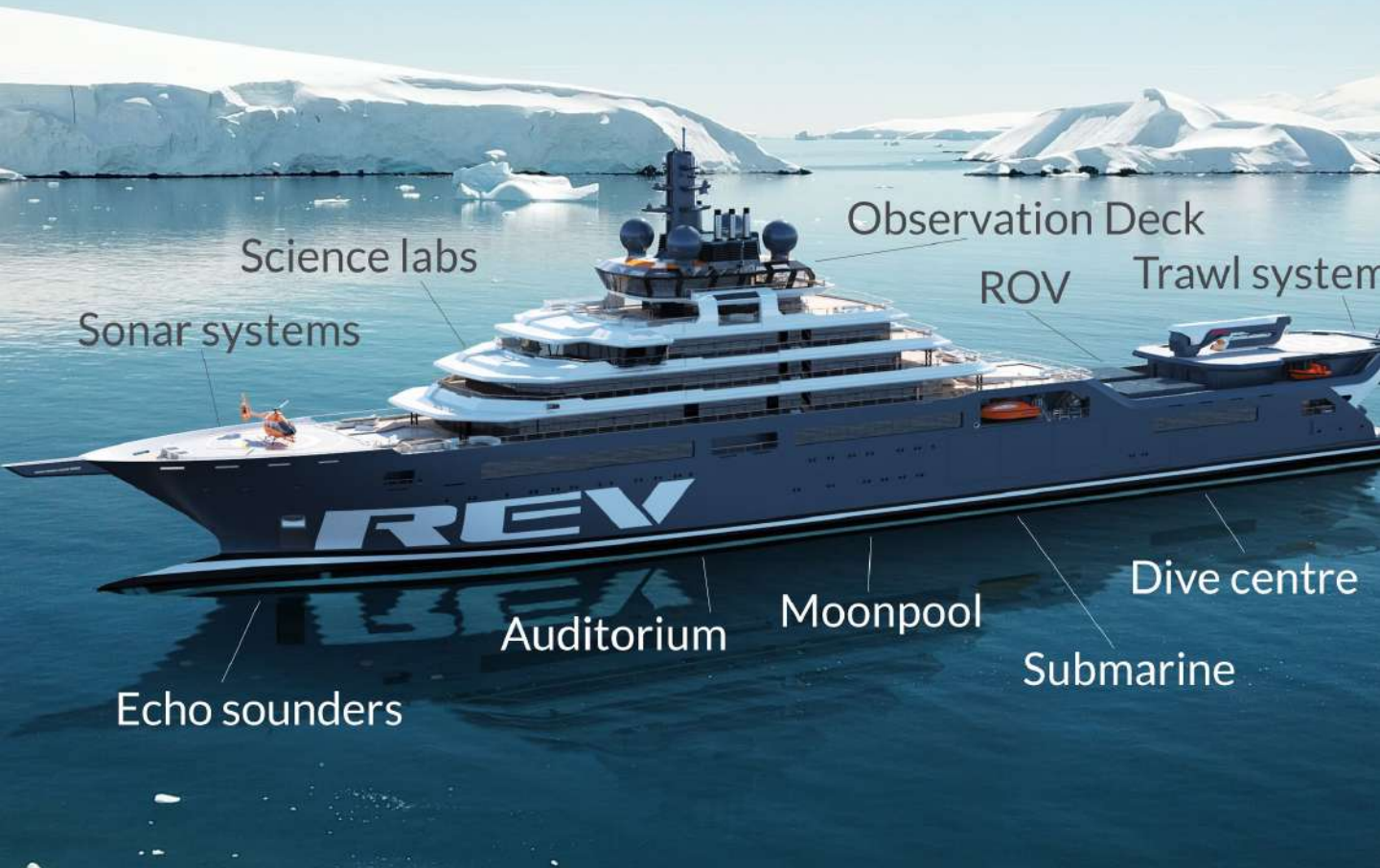
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Preludes



NEUROSCIENCE

What Chess Can Teach Us About Cognition

IN THE NETFLIX SHOW *The Queen's Gambit*, based on a novel by Walter Tevis, a burly custodian in an orphanage basement, hunched over a chess board, intrigues a 9-year-old girl named Beth Harmon, who sees him playing, under a dim light, against himself. This Mr. Shaibel begrudgingly agrees to teach her to play. At night, high on the tranquilizers the staff administers to orphans—this is the early 1960s—she practices tactics in bed, staring up at a chess board that she hallucinates on the ceiling. Beth advances rapidly in skill, and Mr. Shaibel invites the head of the local high school chess group to meet Beth. She ends up playing all the boys in the club, including last year's champion. A crowd of students forms as she bests each one.

As I watched Beth dreamily focus on her imaginary chess board, simulating alternative possibilities, I thought about how that must be shaping her brain,

particularly the part dedicated to planning and decision-making, the frontal cortex. Compared to other regions, it's uniquely malleable, or plastic. Our brains are changing, forming new neural connections and severing others all the time, of course. But at a young age the brain's plasticity is much more pronounced. This is something that Tom Vanderbilt discussed in his *Nautilus* feature, "Learning Chess at 40," in which he reports what it was like taking up the game with his 4-year-old daughter. Psychologist Neil Charness told Vanderbilt, "If you're talking about two novices, your daughter would probably pick things up about twice as fast as you could." In that way it's like learning a language—children can assimilate the game's complex rules and action much more intuitively and quickly than an adult.

This means that chess offers a unique opportunity. It could perhaps be the ultimate window through which we might see how our mental powers shift

Mastering chess appears to have long-lasting effects on the brain.

during our lives. The moves of professional chess players, going back over a century, are recorded, and so researchers can objectively analyze the quality of players' moves over their career, inferring cognitive rise and decline. And that's exactly what a recent study in the *Proceedings of the National Academy of Sciences* did.

An international group of researchers evaluated professional players' move-by-move performance in more than 24,000 games relative to the optimal move a chess engine suggested for each respective move. (These don't include "book moves," the intensively studied game-beginning and game-ending moves, since players routinely deploy them from memory.) The chess engine, an open-source program called STOCKFISH 8, has an estimated Elo-rating exceeding 3,200 points—Elo being the now-universal player-ranking system. The chess-move database includes the moves of current world champion, 29-year-old Magnus Carlsen, who has maintained his title since winning it all in 2013, and as of this year, has an Elo-rating of 2,872.

"This provides a precise and comparable measurement of individual performance for the same individual at different ages over long periods of time, exploiting the advantage of a strictly comparable task and a comparison with an identical performance

benchmark," the researchers write. "Repeated observations for the same individuals allow disentangling age patterns from idiosyncratic variation and analyzing how age patterns change over time and across birth cohorts."

The result is a "hump-shaped profile of performance" over people's lifetimes. Over the last century or so, chess players, the study shows, have been getting better as well as younger. This parallels the so-called Flynn effect in intelligence, or a notable rise in raw cognitive scores. "Performance increased steadily over the course of the 20th century," the researchers write, "but the data also reveal a steepening of the performance increase during the 1990s."

Mastering chess appears to have long-lasting effects on the brain. A 2018 study concluded, after analyzing the brains of almost 30 high-level professional chess players, that "long-term cognitive activities, such as chess, may systematically influence the [white matter] properties of early memory, attention, and visual pathways."

Watching *The Queen's Gambit*, it's as if drugs conferred Beth that advantage pre-computer. Her psychedelic practice sessions offered their own form of immersive and responsive feedback. Mr. Shaibel's surprise at being beaten so readily by a child reminded me of Vanderbilt's own reflection on playing against his daughter. Inexperienced in so many ordinary ways, she was still able to show up an adult who spent some effort trying to learn the royal game. "She was Deep Blue," Vanderbilt wrote, "and I was the human race, being slowly outmoded."

—Brian Gallagher

ANIMALS

How Sea Turtles Find Their Way

THE AIR WAS WARM as the skies grew dark over Diego Garcia, a footprint-shaped atoll in the Indian Ocean's Chagos Archipelago. As the nearly full moon reached its highest point, a green sea turtle scuttled her way onto the sand. It was likely the first time in years she'd set flipper on dry land.

Other than the moments after they hatch and crawl into the surf, sea turtles spend their entire lives in the

ocean. Only when females return to lay eggs on the same beaches where they hatched do they leave the water—just briefly, for a few hours, before slipping back into the sea. Precisely where these now-endangered reptiles go, what route they take to get there, and how they navigate, is a mystery.

Volunteers from the United States military facility on Diego Garcia helped Nicole Esteban, a marine biologist and sea turtle conservationist at Swansea

Turtles are born with a set of instructions that, most of the time, safely delivers them into the open ocean.



University, fasten a GPS transmitter to the top of the turtle's shell while she laid her eggs. The volunteers nicknamed the turtle Serenity and watched as she crept back into the waves and disappeared.

Three months later, Serenity reached her foraging waters along a small island called Farquhar Atoll in the Seychelles archipelago. It is some 4,000 kilometers west of Diego Garcia, but the GPS signals traced a circuitous route that wound through more than 6,000 kilometers of open ocean. Had she had taken a more direct path, she could have accomplished the entire journey in under a month.

It was an unusual trip in other ways, too. Typically when biologists track turtles from their nesting beaches on small islands, most wind up in coastal territory, having paddled across the open ocean until hitting a continental shelf and then turning left or right. But Serenity ended up on a flyspeck island, and many others of her cohort—Esteban's team tagged a total of 35 turtles over five years—followed suit.

"A number of these turtles migrated to very, very small island targets, some not more than a couple of hundred meters square," says Alex Rattray, a biologist at Deakin University who was also involved in the research. It's astonishing enough that a sea turtle can navigate across thousands of miles of open ocean, with no discernible landmarks, and wind up in the correct place. Even more astonishing is when the correct place is a dot of sand with nothing but blue until the horizon in every direction.

In the first month after slipping off the beaches of Diego Garcia, Serenity logged nearly 4,000 kilometers. She was still in the open ocean, north and a little east of Madagascar, at almost precisely the longitude of her final destination in Farquhar Atoll. There was just one problem: She was at the wrong latitude.

The turtle had missed her target by some 200 kilometers. That would be like walking from New York City

to Los Angeles, but accidentally winding up in Tijuana, Mexico instead. But rather than take a right turn and swim north, she kept heading west, farther and farther away from her goal.

We've long suspected that sea turtles use the waves to guide them. When loggerhead sea turtles first hatch on Florida beaches, they swim directly into oncoming waves, a strategy that deposits them into the Gulf Stream, part of a larger network of currents called the North Atlantic Sub-tropical Gyre.

In 1989 a meteorological fluke helped biologist Ken Lohmann confirm that hatchlings use waves as a guide. That year, Hurricane Hugo temporarily caused waves to travel toward the open ocean rather than toward Florida's Atlantic coast. When Lohmann dropped newly hatched turtles into these conditions, they swam into the waves, just as their innate programming instructed them to—and as a result, they went the wrong way.

But what if turtles were to hatch on a calm, windless night with no waves to point the way? Lohmann brought hatchlings into a laboratory to find out. In complete darkness and with no other cues available to guide them, they swam toward the northeast, which in their natural environs would have safely launched them into the Gulf Stream. When he then induced an artificial magnetic field around the tanks, the turtles continued in what they thought was a northeasterly direction. In reality, thanks to Lohmann's magnetic misdirection, they were swimming in precisely the opposite direction. The results confirmed that they really did use Earth's magnetic field.

Taken together, Lohmann's experiments revealed that sea turtles hatch with at least two strategies for finding their way pre-programmed into their brains: the movement of waves and the Earth's magnetic field. Turtles are born with a set of instructions that, at least most of the time, safely delivers them into the open ocean.

Lohmann suspected that something more sophisticated than a magnetic compass alone keeps sea turtles on a safe trajectory. When he exposed turtle hatchlings to artificial magnetic fields that mimicked those found off the coast of Portugal, they began swimming south, which would decrease their chances of ending up in frigid northern waters. When he adjusted the field to imitate those in the open ocean west of Africa, the turtles swam toward the northwest, likewise ostensibly enabling them to remain within the gyre. Sea turtles are born not just with a magnetic compass, but also with a magnetic map.

Despite these sophisticated systems, however, adult turtles like Serenity do make mistakes. From the ocean north of Madagascar, she would travel almost 600 kilometers further west before apparently realizing she was off course.

“One limitation of tracking studies is they can provide you with the track that a turtle followed but they can never tell you exactly what the turtle was thinking or the reasons it chose to go along that particular route,” says Lohmann when I ask him to review the courses taken by Serenity and the other turtles in Esteban’s study.

There was no correlation between wind or current and when turtles arrived at their destination, or even when they changed direction. A more likely explanation is that the turtles’ inherited magnetic map is simply so crude that large deviations are to be expected. That evolution endowed them with a fairly coarse-grained map isn’t very surprising, given the imperfections of Earth’s magnetic field.

The field is formed by movements of liquified iron and nickel within the planet’s core, a phenomenon called magneto-hydro-dynamics that geophysicists are still working to fully understand. Because those metals swirl around somewhat erratically, the resulting magnetic field winds up being somewhat uneven as well.

Despite localized unevenness, though, Earth’s magnetic field is still broadly predictable. It varies in strength, with a weaker pull near the equator and a stronger pull near the poles. It also varies in its inclination, or the angle at which magnetic field lines intersect with the planet’s surface.

If sea turtles were sensitive to just one of these parameters—strength or inclination—then they could derive their position along a roughly north-south axis. Because sea turtles can detect both features, they can also derive their position on an east-west axis.

Before long, Serenity had reached Aldabra Atoll, famous for its giant land tortoises. “For a month, this turtle just sat here west of Aldabra and just went around in circles basically,” Rattray recalls. He assumed that Aldabra was her target, and that she was having a bit of trouble sorting out its precise location relative to her own.

Then a day came when Serenity abruptly reversed course and began moving in almost a straight line directly to Farquhar Atoll, some 600 kilometers to the east. She finally reached her destination on New Year’s Eve, nearly three months after leaving Diego Garcia.

—Jason G. Goldman

PSYCHOLOGY

Why We Judge People Based on Their Relatives

IMAGINE YOU’VE MOVED into a new neighborhood. You and your new neighbor, Jack, quickly build a friendly rapport and, after a couple weeks, you give him a set of keys, in case of emergency. One day, returning his hammer you borrowed, you see a young guy stumbling out of Jack’s front door, a laptop in one arm, a fur coat in the other. He doesn’t seem sober. Suddenly Jack runs up and says to his son, “Stop it Pete! You told me you wouldn’t do this again!” Pete drops the

goods and runs off. “Pete’s an addict,” Jack tells you. He changes his locks often, he explains, because Pete comes over and steals from him and his wife.

Who wouldn’t feel terrible for Jack? He seems like a good guy. Yet you find yourself rethinking giving him your house keys. Do you change your opinion of him based on the fact that his son is an addict, and a thief?

We know that humans are inference machines. With very little information, people can guess at rates above

People aren't bad at guessing how heritable certain human traits are.

chance whether someone is a psychopath. To many, “stereotype” is a word practically synonymous with “false,” but stereotype accuracy is one of the best replicated findings in psychology. You can accurately infer a lot about someone simply by knowing their ethnicity, sex, or country of origin. Of course, when we know people better, we tend to rely relatively more on our own experience.

So how might you think about Jack in light of meeting Pete? You might be someone who thinks that the environment has a strong influence on people's personality, and that having negligent or otherwise bad parents is a major way for people to become dysfunctional. Historically, it was common to blame people's parents for their ills. You could also change your assessment of Jack for genetic reasons. Behavioral genetics looks at where individual differences come from—whether from family upbringing and life experience, or genetic factors. Or from both (for example, parents could choose to buy more books because their kid shows a lot of natural interest in reading).

For most characteristics, it looks like genetics are much more important than parenting. One large study found that the rate of criminality for adopted children was 12 percent if their biological parents were criminals but their adopted parents were not—but just 6 percent if their adoptive parents were criminals and their biological parents were not. When both sets of parents were criminals, the rate of criminality shot up to 40 percent. There is a similar pattern when it comes to drug and alcohol abuse.

I'll call this judgement we make about others, on the basis of their relatives, “intuitive behavioral genetics.” Research has shown that people aren't bad at guessing how heritable certain human traits are (interestingly, it's mothers of multiple children who are the best at guessing heritability).

It's surprising that there is almost no research about how much we judge people based on their relatives, given the abundance of evidence showing that we make quick inferences about other people on the basis of little information. Some sociologists have looked into a related bias, called the “courtesy stigma.” If you associate with someone who is stigmatized in society, like someone with substance-abuse problems, schizophrenia, or a cognitive disability, that stigma can fall on you. “Family stigma” is one form of courtesy stigma.

People are more likely to think that a son or daughter is likely to have substantial difficulties if they find out the father of this person is in prison, depressed, or an alcoholic than if he is away much of the time, or elderly. Another study found that most people who had a family member with schizophrenia wanted to hide this information from others.

Because most sociological research still rarely considers the role of behavioral genetics, many scholars hold that humans stigmatize the close relatives of people with significant dysfunction for reasons of mere proximity. But this stigmatization may result from a heuristic that these close relatives are likely to share this dysfunction.

If this tactic derives at least part of its power from the fact that we infer what people are like based on their families, it suggests our psychology is significantly genetically determined. On some level, then, we may be psychologically disposed to track people's genetics for insight into their behavior. Similar to stereotypes, intuitive behavioral genetics, especially when it's used to stigmatize, isn't moral or kind—but we can safely expect humans to judge others with whatever information they're privy to, including blood relations. And sometimes it's warranted.

Perhaps Jack once shared Pete's problems but has learned enough about how to manage himself now to be a trustworthy neighbor and friend. Many men become less troubled and troublesome as they age. As Jack's neighbor, Pete has certainly given you a better idea of what to watch out for. Yet regardless of what you know about Jack's family, getting to know him personally will give you the best insight into who he is, and what kind of neighbor he'll be. Intuitive behavioral genetics may sometimes be reliable in sizing people up, but should hardly be the only thing you rely on.

—Diana Fleischman

FOOD

The Dense, Bushy Future of Food

THE WAY WE LIVE is out of balance with the way we eat. About 11 percent of the Earth's land area is used for agriculture; meanwhile, two-thirds of the human population is now jammed in cities, which cover a mere 3 percent. Continued urbanization and population growth will require more farmland, more transportation, and an even bigger ecological footprint—unless we can find more efficient ways to feed the world.

One intriguing solution is to give traditional agriculture a 90 degree twist into vertical farming, where crops are grown indoors in tightly stacked rows, sustained hydroponically so that they don't need dirt. A lot of food production could then be relocated to urban regions, so that less wilderness would need to be converted to cropland, notes Choon-Tak Kwon, a postdoctoral fellow in plant biology at Cold Spring Harbor Laboratory. The financial and ecological cost of transporting food should decrease substantially, too. "You can grow perishable crops near your home all the year around," Kwon says, ideally leading to "fresher foods with stable prices."

The diversity of crops that can be grown indoors must increase.

We know that the basic concept works. Vertical farming and related forms of urban agriculture already account for a little over 15 percent of the world's agricultural production, according to the U.N. Food and Agriculture Organization. But that yield is dominated by a few crops—mostly leafy greens—that grow well inside, limiting the potential for further expansion.

For urban agriculture to have a meaningful impact on preserving wild habitats, "the diversity of crops that can be grown indoors must increase," argues Cathryn O'Sullivan, an agricultural scientist. Trouble is, most major crops are too big and gangly to grow well in the confined spaces of vertical farms. Ramping up urban food production will therefore require changing not just *how* farmers grow crops, but also *what* they grow.



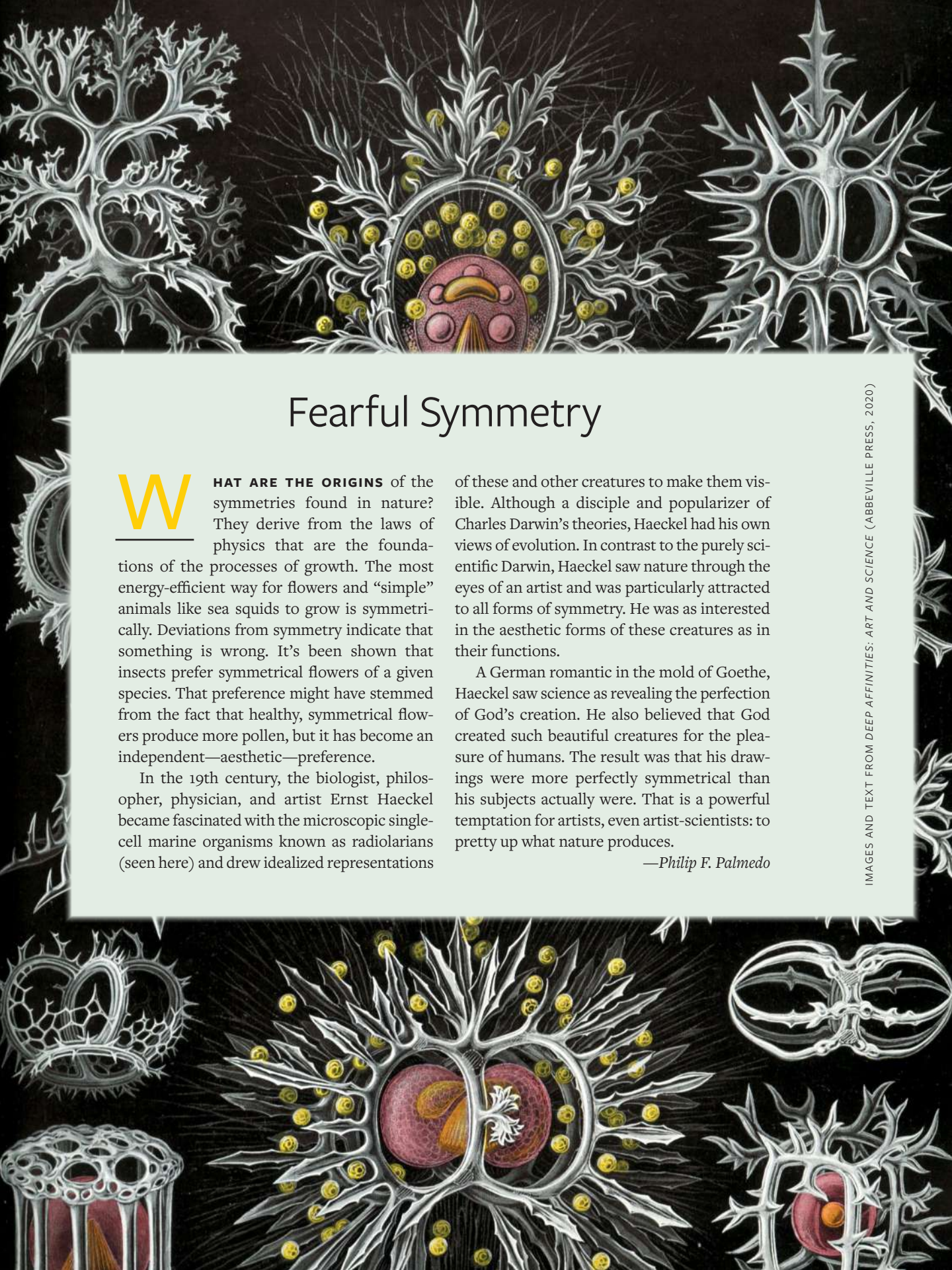
Kwon decided to take tomato plants as his test case. He set out to determine whether it is possible to radically shrink tomatoes' stems without compromising their fruit yield.

During a series of lab experiments, Kwon and his colleagues discovered a set of mutations that lead to shorter tomato plants that produce fruit more quickly. These plants would be well suited to vertical farms. Then the researchers used a gene-editing molecular tool called CRISPR-Cas9 to insert the mutations into a commonly grown crop, the Sweet 100 cherry tomato. The result was an absurdly dense-looking plant, roughly a quarter-meter tall but jammed with grape-like bunches of cherry tomatoes. Even better, the first cherries were ready for harvest just a little over a month after seedlings sprouted, about two weeks faster than the regular variety.

Kwon normally stashes away the fruits of his experiments, saving the seeds to grow new plants, but when he saw the first big cluster of tomatoes from his triple-edited plant, "I just tried it," he says. He liked them so much that he started bringing home extras for his wife to use in salads. That bounty has since expanded; he and his team have found that inserting the same genes into other tomato varieties results in similarly compact, rapidly-bountiful plants. Next, he wants to see if this gene set works on additional crops in the same family, such as eggplants and peppers.

The potential payoffs go well beyond preserving and restoring wilderness. Urban agriculture could lead to reduced use of water, fertilizers, and pesticides. It could also make the food supply more robust and secure.

—Christie Wilcox



Fearful Symmetry

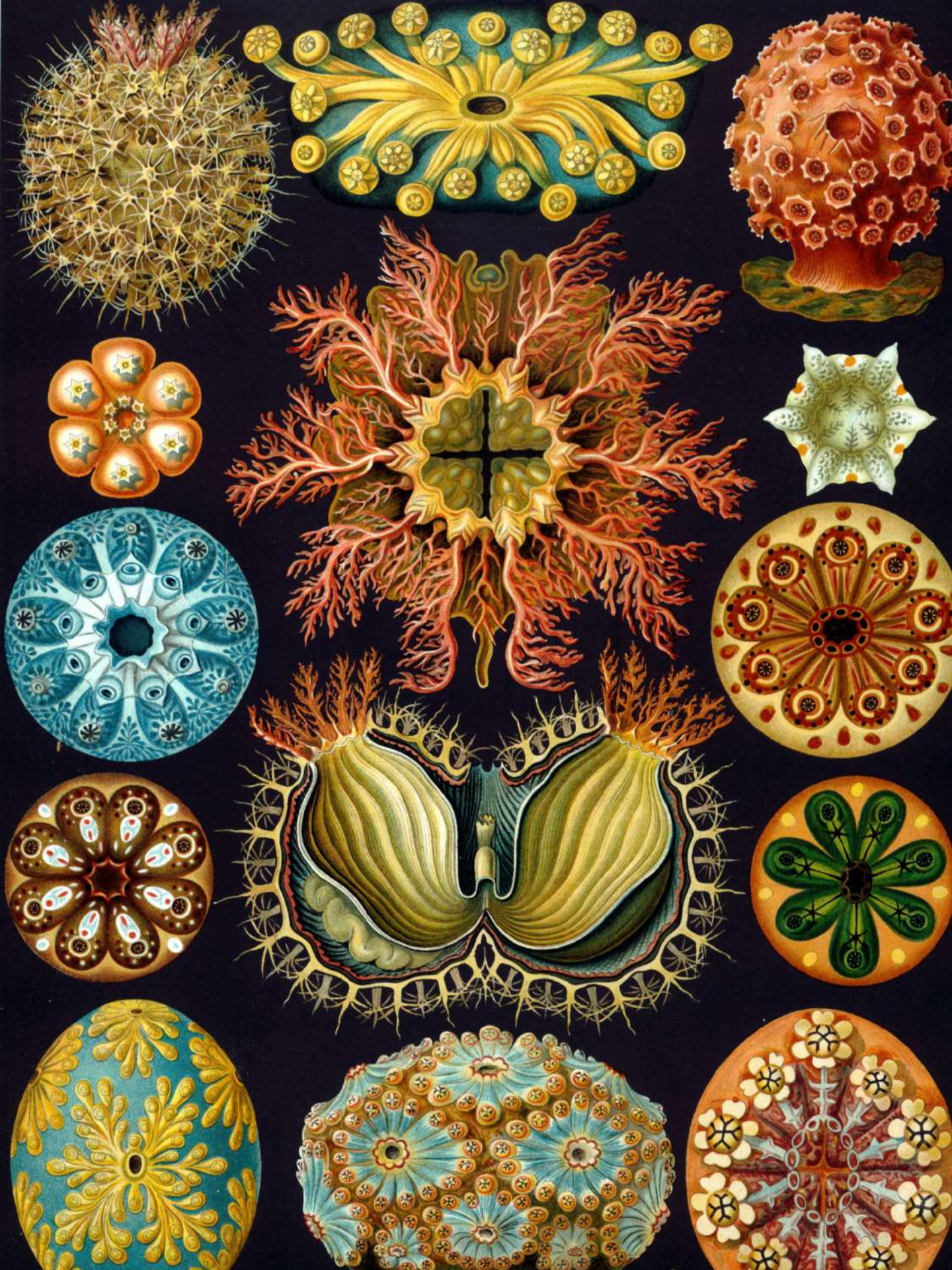
WHAT ARE THE ORIGINS of the symmetries found in nature? They derive from the laws of physics that are the foundations of the processes of growth. The most energy-efficient way for flowers and “simple” animals like sea squids to grow is symmetrically. Deviations from symmetry indicate that something is wrong. It’s been shown that insects prefer symmetrical flowers of a given species. That preference might have stemmed from the fact that healthy, symmetrical flowers produce more pollen, but it has become an independent—aesthetic—preference.

In the 19th century, the biologist, philosopher, physician, and artist Ernst Haeckel became fascinated with the microscopic single-cell marine organisms known as radiolarians (seen here) and drew idealized representations

of these and other creatures to make them visible. Although a disciple and popularizer of Charles Darwin’s theories, Haeckel had his own views of evolution. In contrast to the purely scientific Darwin, Haeckel saw nature through the eyes of an artist and was particularly attracted to all forms of symmetry. He was as interested in the aesthetic forms of these creatures as in their functions.

A German romantic in the mold of Goethe, Haeckel saw science as revealing the perfection of God’s creation. He also believed that God created such beautiful creatures for the pleasure of humans. The result was that his drawings were more perfectly symmetrical than his subjects actually were. That is a powerful temptation for artists, even artist-scientists: to pretty up what nature produces.

—Philip F. Palmedo



The Synchronicity of Wolfgang Pauli and Carl Jung

How the theoretical physicist and analyst came together and then apart

BY PAUL HALPERN

IGOR KISSELEV / SHUTTERSTOCK

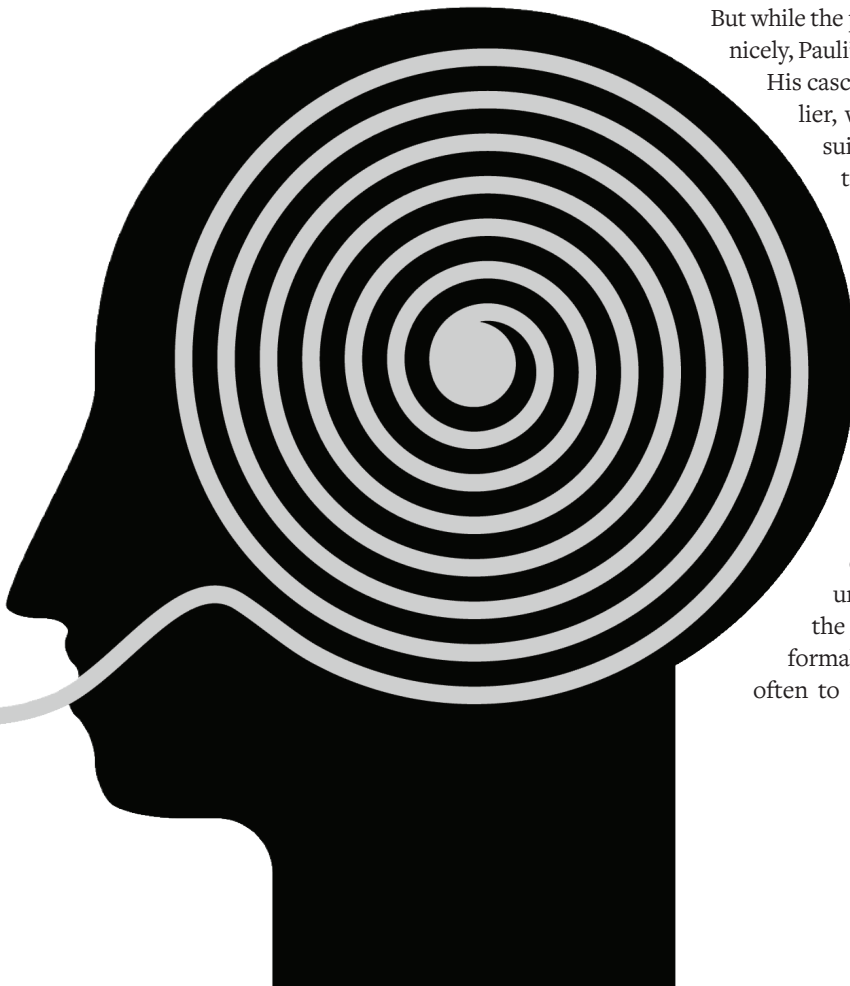


BY THE END OF 1930, Austrian-born theoretical physicist Wolfgang Pauli was at the height of his achievements, yet an absolute emotional wreck. His brilliant contributions to science—such as the famous exclusion principle that would eventually earn him a Nobel Prize—had cemented his reputation as a genius. Remarkably, it demonstrated, among other consequences, why the electrons in an atom don't all cluster together in the lowest energy quantum state and render it unstable. He had also predicted the existence of a lightweight, electrically neutral particle—later dubbed the neutrino—that, while yet to be found experimentally, already offered a way forward in understanding a radiative process called beta decay.

But while the particle world was starting to shape up nicely, Pauli's own world was crashing around him.

His cascade of troubles began three years earlier, when his beloved mother committed suicide, at the age of only 48, in reaction to his father's infidelity. Within a year his father remarried, wedding an artist who was in her late 20s—around the same age as Pauli at the time. Pauli derided his father's decision and nicknamed his father's new wife "the evil stepmother."

By then, while Pauli's career was boosted by being appointed to a professorship at the ETH [Swiss Federal Institute of Technology] in Zurich, he had become increasingly disillusioned. For reasons not entirely understood, in May 1929 he abandoned the religion of his birth, Catholicism, by formally leaving the Church. Pauli traveled often to Berlin, where Einstein, Schrödinger,



One of the remarkable aspects of the Pauli–Jung collaboration was how their rhetoric had begun to converge.



Planck (then emeritus, but still active), and other luminaries made it one of the major hubs of theoretical physics. During one of his visits to that city he met the cabaret dancer Käthe Deppner and began dating her. She had another boyfriend at the time, a chemist, but was open to Pauli's interest. He proposed marriage to her, which for some reason she accepted, despite his being far from the man of her dreams. They wed in December 1929.

It was a troubled marriage from the start. Her interest in the chemist had not waned and she continued to see him. After a few weeks, she essentially ignored her husband. Pauli spent most of the next year in Zurich; she remained in Berlin. By November 1930 they were divorced. To Pauli's chagrin, she ended up with the chemist. "Had she taken a bullfighter, I would have understood, but such an ordinary chemist ..." he bemoaned.

With his emotional life in shambles, Pauli took up drinking and smoking heavily. He became a familiar presence at Mary's Old Timers Bar, a Zurich tavern styled after American speakeasies. It is remarkable that his neutrino idea had emerged around the same time. He was focused enough to remain productive even with his life in crisis. Pauli's father decided to intervene, suggesting that he seek out Carl Jung for therapy.

Pauli was familiar with Jung's work, as he spoke often at the ETH. Agreeing to his father's suggestion, Pauli contacted Jung and made an appointment. By that point, he was desperate to get his inner life back on track and hoped that therapy might make a difference. Pauli expected to be treated by the founder of analytical psychology himself, but Jung assigned him to his young assistant, Erna Rosenbaum. Jung explained that given Pauli's issues with women he might best be analyzed at first by a female therapist. Her role was to write down Pauli's dreams until he was confident enough to jot them down himself.

Rosenbaum's treatment of Pauli began in February 1932 and lasted about five months. Then, Pauli was placed in the driver's seat, noting his own dreams for about three months in a kind of self-analysis. Finally, Jung took over personally as his therapist for the following two years. Once Jung started treating Pauli directly, he already had more than 300 recorded dreams to analyze, greatly aiding him in shaping his therapeutic suggestions. In addition to sharing his dreams, Pauli opened up about his emotional turmoil, erratic behavior, alcohol dependency, and issues dealing with women.

For Jung's studies of the impact of the collective unconscious on the psyche, including the roles of dreams and fantasies, he sought out subjects with vivid recall. His developing notion of synchronicity, based as it was on dynamic Einsteinian notions of space and time, could certainly benefit from a physicist's voice. A prominent quantum physicist, who happened to have complex dreams he could remember with ease, was an extraordinary find.

Ultimately, either directly or indirectly, Jung compiled roughly 1,300 of Pauli's dreams and would make use of them (while maintaining patient confidentiality) for his research studies. Consequently, as the scholar Beverley Zabriskie wryly points out, "Readers of ... Jung are more familiar with Wolfgang Pauli's unconscious than with his waking life and achievement." It is a mystery how Pauli remembered so many dreams in such great detail. Truly, his recall was phenomenal, and he must have trained himself in some manner. The dreams added immensely to the resources Jung could draw upon in crafting his theories.

But of course, it wasn't just a research project. Jung genuinely wanted to help Pauli become more aware of his stifled feelings. The gist of Jung's treatment was to show Pauli how his emotional self, symbolized by the anima archetype, was repressed in favor of pure intellect. Pauli came to understand how his life was imbalanced. Gradually, over two years of therapy, he would become more settled—at least for a time. Finally able to maintain a mature relationship, in 1934 he married Franciska "Franca" Bertram in London. Around the same time, he decided to end his private

therapy sessions. He was feeling more stable and had cut back—at least temporarily—on his drinking.

Though no longer a patient, Pauli would keep up his correspondence with Jung until almost the end of his life, including sharing his dreams. They'd continue to speculate together about their significance and connections to archetypes. With a brilliant mathematical mind engaged in unraveling the deepest questions in theoretical physics, it is not surprising that many of Pauli's dreams had geometric elements and abstract symbols. They'd often include symmetric arrangements of circles and lines, which Jung would interpret in light of his notion of archetypes. As mathematical physics fed Pauli's visions, which Jung connected with ancient symbolism, the two thinkers ended up weaving profound metaphorical connections between the two realms.

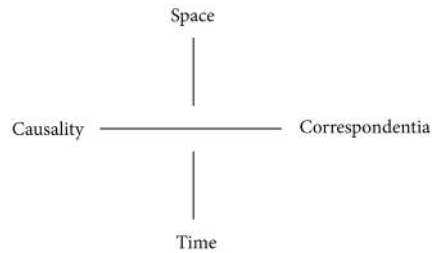
Pauli wrote to Jung reporting a dream he had about a physics congress with many participants. The dream had numerous images representing physical examples of polarization (separation of one thing into two opposites), including electric dipoles (balanced arrangements of positive and negative charges) and the splitting of atomic spectral lines within an applied magnetic field. Jung responded the dream symbolism likely represented "the complementary relationship in a self-regulating system [including] man and woman."

A saying attributed to Freud is that "sometimes a cigar is just a cigar." As a physicist, wouldn't Pauli naturally sometimes have dreams with physics-related content? Couldn't it be that "sometimes a dipole is just a dipole," not a symbolic union of man and woman? Jung, like Freud, recognized that possibility and was generally careful not to be dogmatic in his conclusions.

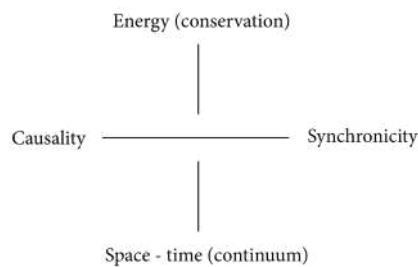
Another of Pauli's dreams included an ancient symbol called the Ouroboros: a serpent devouring its own tail while coiled into a circle. Such symbolism, related to the yin-yang icon of Taoism, reflects the concept of eternal destruction and rebirth, including the turning of the seasons and the recycling of the natural elements. Such a figure also displays the rotational symmetry that Pauli and others employed in their explorations of quantum properties. Drawing from a term in Eastern philosophy, it also forms a rudimentary kind of mandala.

ONE OF THE REMARKABLE ASPECTS of the Pauli–Jung collaboration was how their rhetoric had begun to converge. Thanks to Pauli, Jung had become far more knowledgeable about quantum physics, including its chance aspects and the role of observers. Thanks to Jung, Pauli had become immersed in the studies of mysticism, numerology, and ancient symbolism.

Around that time, Jung began to hone his notion of synchronicity in preparation for developing a treatise on the subject. With the help of Pauli, he hoped to shape it into a key principle acknowledged by the psychological community. As part of that goal, he aspired to develop his own emblem—a quaternio—as shorthand for how nature is connected. Jung would schedule a two-part series of talks on the subject. In preparation for the lectures, in 1950, he sent Pauli a letter that included a quaternio diagram that juxtaposed causality with correspondentia (a term referring to acausal connections analogous to the Hermetic law of correspondence) and space with time. It looked like:



On Nov. 24, 1950, after having a chance to think about Jung’s diagram, Pauli responded with a critique about his division of space and time into opposites. Einstein’s revolution, Pauli pointed out, merged space and time into a single entity—space-time—not opposites. Instead, he suggested a modified diagram (which Jung accepted with slight further modifications):



Pauli’s contrast of energy (and momentum) with space-time matched the dichotomy posed by the relativistic version of Heisenberg’s uncertainty principle. The more that is known about space-time, the less that is known about energy-momentum (similarly a four-dimensional entity in relativity), and the converse.



DUALITIES During his therapy with Carl Jung (left), Wolfgang Pauli (right) came to embrace Jung's archetypal idea of dualities, such as the contention that men tend to suppress their female sides (anima) and women their male sides (animus). Ultimately those interests led Pauli to look further into symmetries in physics.

A prominent quantum physicist, who happened to have complex dreams, was an extraordinary find.

Pauli's concept of causality, called "statistical causality," which Jung came to adopt as well, was distinct from mechanistic models. He argued that given the random outcomes in certain kinds of individual quantum measurements, such as determining whether or not a radioactive sample has exhibited a single decay within a certain time frame, the law of cause and effect needed to include the notions of chance and averaging.

The results of experiments are predictable only once the researchers take averages over many trials. In the same letter, Pauli connected synchronicity with parapsychologist J.B. Rhine's mind-reading research: "As you yourself say, your work stands and falls with the Rhine experiments. I, too, am of the view that the empirical work behind the experiments is well-founded."

Enthusiastic about Pauli's suggestions, Jung responded with the bold proposal of generalizing synchronicity to include acausal relationships without a mental component—that is, purely physical interactions. He did not specify quantum entanglement, but surely that fell into Jung's expanded definition.

Ironically, his generalization served to decouple the concept of synchronicity from the Rhine results, precisely at the same time he and Pauli were embracing them. A broad definition of synchronicity as any acausal connecting principle encourages exploration of how the universe is intertwined through symmetry and additional mechanisms other than the chain of cause

and effect. With some reservations, Pauli saw merit in Jung's expanded definition. Any extension to physical processes, he emphasized, needs to move beyond psychological terms, such as archetypes, that would not be appropriate.

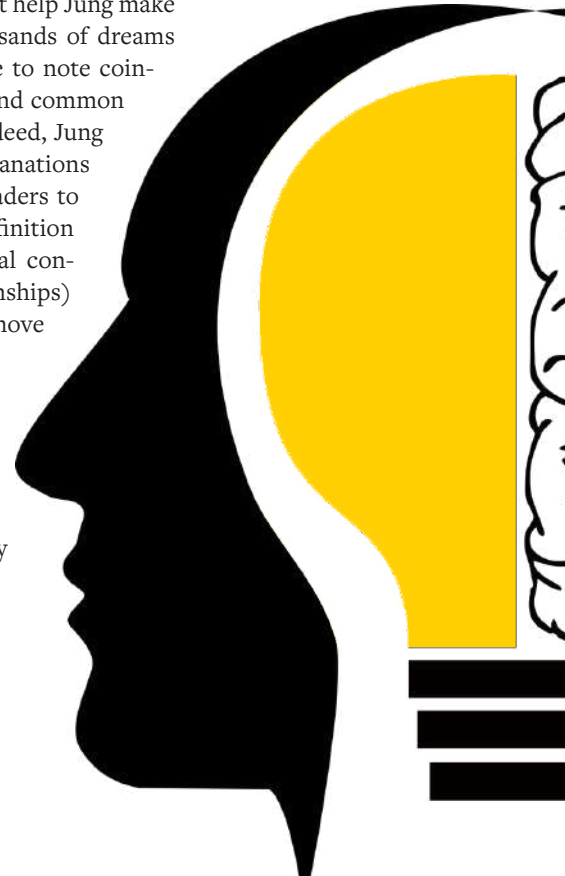
He wrote to Jung on Dec. 12, 1950: "[T]he more general question seems to be the one about the different types of holistic, acausal forms of orderedness in nature and the conditions surrounding their occurrence. This can either be spontaneous or 'induced'—i.e., the result of an experiment devised and conducted by human beings."

In 1952, as the culmination of their collaboration, Jung and Pauli published a joint volume, *Naturerklärung und Psyche* (*The Interpretation of Nature and the Psyche*). It included two treatises, "Synchronicity: An Acausal Connecting Principle," by Jung, and "The Influence of Archetypal Ideas on the Scientific Ideas of Kepler." Their combined work effectively outed (for anyone who read it closely) Pauli as the source of Jung's dream material. Decades later, the first part (Jung's section) would be released as a popular paperback. It contained Jung's famous anecdote of the scarab, as an example of the "meaningful coincidence" he associated with synchronicity:

A young woman I was treating had, at a critical moment, a dream in which she was given a golden scarab. While she was telling me this dream, I sat with my back to the closed window. Suddenly I heard a noise behind me, like a gentle tapping. I turned round and saw a flying insect knocking against the window-pane from the outside. I opened the window and caught the creature in the air as it flew in. It was the nearest analogy to a golden scarab one finds in our latitudes, a scarabaeid beetle ...

For scientific minds, such anecdotal evidence did not help Jung make his case. Any psychotherapist who has analyzed thousands of dreams by various patients would be bound by simple chance to note coincidences at some point between elements in dreams and common events in real life, such as encounters with insects. Indeed, Jung freely acknowledged that there were alternative explanations for each of the stories he told—he just wanted his readers to note a pattern. Greater emphasis on his generalized definition of synchronicity, which encompassed physical acausal connections (such as entanglement and symmetry relationships) would have made a stronger argument for the need to move beyond pure causality.

But as it stood, Jung's combination of incidents, dreams, and mythology won over few scientific adherents, aside from Pauli. One review of the book, written anonymously by an eminent mathematician, concluded: "After thoroughly studying their writings for many months now, I have come to see clearly that they are both utterly mad."



“After thoroughly studying their writings for many months now, I have come to see clearly that they are both utterly mad.”

IN AUGUST 1957, Pauli and Jung exchanged the final letters in their lengthy correspondence. Pauli’s note to Jung that month was one of his longest, including a long description of a dream and exposition about symmetries in physics. Jung responded with great interest to Pauli’s letter, interpreting the dream Pauli mentioned as symbolic of the reconciliation of opposites, such as psyche and body. Jung suggests that parity symmetry violation in the weak interaction is analogous to an arbiter—called the “Third”—taking sides between two otherwise symmetrically opposite entities. The Third might slightly favor psyche over body, breaking the symmetry between them. The rest of Jung’s note delved into his new interest in UFOs (Unidentified Flying Objects), which he had concluded are either real (from space) or a new kind of mythology with its own archetypes.

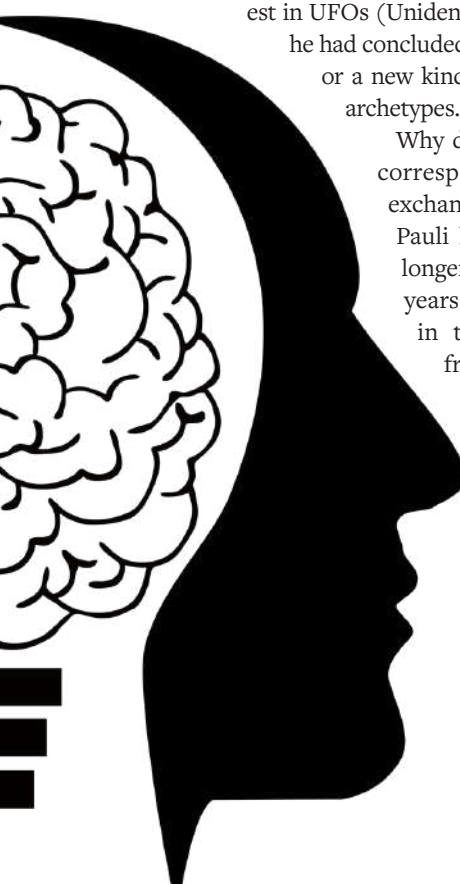
Why did Pauli and Jung’s lengthy correspondence end with that exchange of letters, even though Pauli lived for more than a year longer? A gap of months or even years sometimes happens even in the letter-writing of good friends. Moreover, as we’ve seen in his attitude toward other physicists, Pauli was in his heart a skeptic. He critically examined any dogma, including Jung’s. He complained to Bohr, for

instance, about some of the vagaries of Jung’s approach: “The Jung school is more broad minded than Freud has been, but correspondingly less clear. Most unsatisfactory seems to me the emotional and vague use of the concept of ‘Psyche’ by Jung, which is not even logically self-consistent.” Pauli also began to cast doubt on Rhine’s methods. In a letter to Rhine, dated Feb. 25, 1957, but received only after his death, Pauli asked Rhine about an article he had heard about that was critical of parapsychology. Rattled by the letter, Rhine complained to Jung, who tried to track down the critical piece but found no evidence of its existence.

Further impetus for Pauli to disassociate from Jung was the latter’s obsession with UFOs. Pauli was curious about that question, but not enough to devote the time to it for which Jung might have hoped. That period corresponded to a major collaboration on unified field theory Pauli conducted with Heisenberg. Additionally, Pauli’s stamina began to decline in his final year before he was diagnosed with pancreatic cancer. Thus a host of factors might have led to the end of the long, productive dialogue. ☺

PAUL HALPERN, a professor of physics at the University of the Sciences in Philadelphia, is the author of *Synchronicity: The Epic Quest to Understand the Quantum Nature of Cause and Effect*. His other books include, most recently, *The Quantum Labyrinth* and *Einstein’s Dice and Schrödinger’s Cat*.

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PROTECTING OUR FUTURE





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“In every outthrust headland, in every curving beach, in every grain of sand there is the story of the earth.”

Rachel Carson

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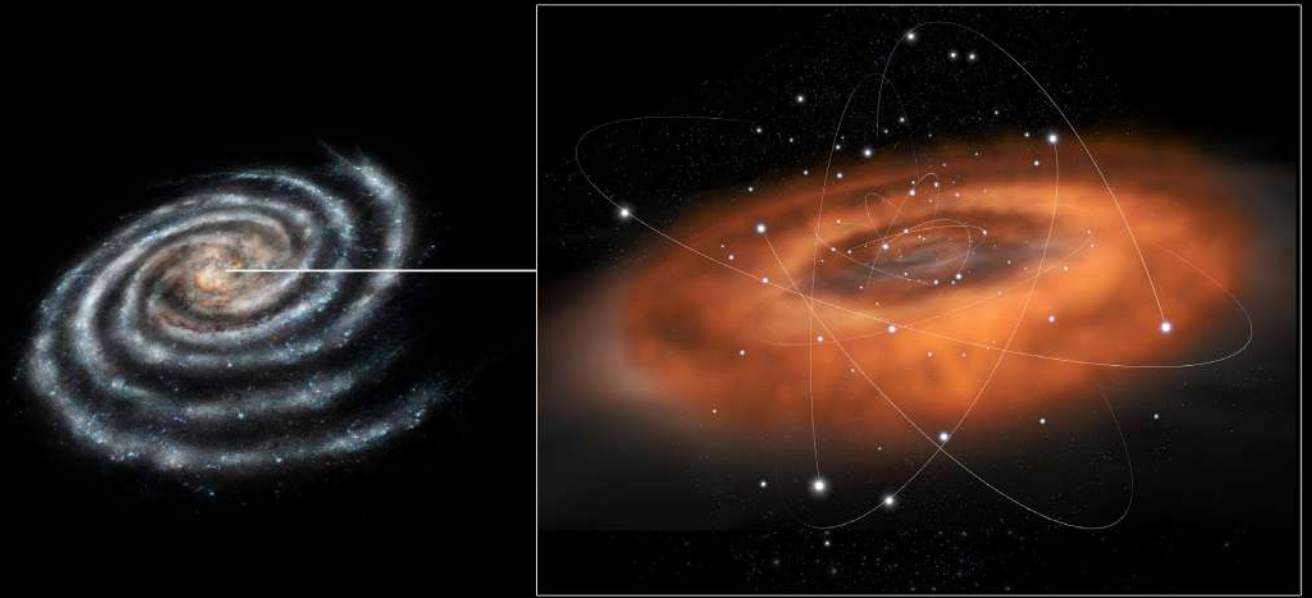
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A Supermassive Lens on the Constants of Nature

What this year's Nobel-winning discovery of the black hole at our galaxy's center reveals

BY SIDNEY PERKOWITZ

THE 2020 NOBEL PRIZE in Physics went to three researchers who confirmed that Einstein's general relativity predicts black holes, and established that the center of our own galaxy houses a supermassive black hole with the equivalent of 4 million suns packed into a relatively small space. Besides expanding our understanding of black holes, the strong gravitational field around the supermassive black hole is a lab to study nature under extreme conditions. Researchers, including one of the new Nobel Laureates, Andrea Ghez at the University of California, Los Angeles, have measured how the intense gravity changes the fine structure constant, one of the constants of nature that defines the physical universe, and in this case, life within it. This research extends other ongoing efforts to understand the constants and whether they vary in space and time. The hope is to find clues to resolve issues in the Standard Model of elementary particles and in current cosmology.

Besides Ghez, the other Nobel Laureates honored in 2020 are Roger Penrose at Cambridge University, who deepened our theoretical understanding of black holes; and Reinhard Genzel of the Max Planck Institute for Extraterrestrial Physics in Garching, Germany. Ghez and Genzel carried out parallel but separate observations and analysis that led each to deduce the presence of our galactic supermassive black hole. At 27,000 light-years away, obtaining good data required huge telescopes. Ghez worked with the Keck Observatory on Mauna Kea in Hawaii, and Genzel used the Very Large Telescope in Chile. Each researcher found that the motion of the stars they observed arose from an enormous mass at the center of the galaxy. They obtained the same value, 4 million times the mass of our sun, in a region only as big as our solar system—definitive evidence of a supermassive black hole.

The constant in the strong gravity near the black hole could be a clue to modifying the Standard Model.

Ghez's research at Keck made her a co-author in a paper published this year, in which Aurélien Hees of the Paris Observatory and 13 international colleagues presented results for the fine structure constant near our galactic supermassive black hole. Remarkably, Ghez's Nobel Prize-winning results supporting this research combined today's theories and astronomical techniques with ideas dating back to Johannes Kepler and Isaac Newton to examine the motion of stars near the supermassive black hole. This is another example of Newton's insight about how science advances when he wrote in 1675, "If I have seen further it is by standing on the shoulders of giants."

German astronomer Kepler is one such giant who changed science when he presented his laws of planetary motion in 1609. He was the first to show that the planets do not orbit the sun in divinely inspired perfect circles, as had been assumed. The orbits are ellipses with the sun at a focus of the ellipse, one of the two points symmetrically offset from the center that define how to construct an ellipse. Kepler also found a mathematical relation between the size of a planetary orbit and how long it takes the planet to complete a circuit.

In 1687 Newton gave Kepler's laws a deeper, more coherent physical basis. Newton's law of gravitation, based on mutual attraction between bodies, showed that a celestial object in a closed orbit around a mass follows an elliptical path that depends on that mass. This result, which today is taught in introductory

astronomy, is the heart of how Ghez found the mass of the supermassive black hole. Her years of careful observations precisely defined the elliptical paths of stars orbiting the galactic center; then she used Newton's theory to calculate the mass at the center (general relativity, which replaces Newton's law, predicts black holes but Newton's approach is sufficiently accurate for the stellar orbits around the supermassive black hole). Knowledge of these orbits would be crucial for measuring the fine structure constant in the strong gravity near the supermassive black hole. How that constant depends on gravity could be a clue to modifying the Standard Model or general relativity to deal with dark matter and dark energy, the two great puzzles of contemporary physics.

THIS PARTICULAR EXAMINATION fits into a bigger, long-term examination of the fundamental constants of nature, each of which tells us something about the scope or scale of our deepest theories. Along with other constants, the fine structure constant (denoted by the Greek letter α), appears in the Standard Model, the quantum field theory of elementary particles. The numerical value of α defines how strongly photons and electrically charged particles interact through the electromagnetic force, which controls the universe along with gravity and the strong and weak nuclear forces. Among its effects, electromagnetism determines the degree of repulsion between protons and how electrons behave in an atom.

If the value of α were much different from the one we know, that would affect whether nuclear fusion within stars produces the element carbon or whether atoms can form stable complex molecules. Both are necessary for life, another reason α is significant.

Other constants represent other major physical theories: c , the speed of light in vacuum, is crucial in relativity; h , the constant derived by Max Planck (now taken as “ h -bar,” or $\hbar = h/2\pi$), sets the tiny size of quantum effects; and G , the gravitational constant in Newton’s theory and general relativity, determines how astronomical bodies interact. In 1899 Planck used just these three to define a universal measurement system based on natural properties and not on any human artifacts. This system, he wrote, would be the same “for all times and all civilizations, extraterrestrial and non-human ones.”

Planck derived natural units of length, time, and mass from c , h , and G : $L_P = 1.6 \times 10^{-35}$ meters, $T_P = 5.4 \times 10^{-44}$ seconds, and $M_P = 2.2 \times 10^{-8}$ kilograms. Too small to be practical, they have conceptual weight. In today’s universe the gravitational interaction between elementary particles is too weak to affect their quantum behavior. But place the bodies a tiny Planck length L_P apart, less than the diameter of an elementary particle, and their gravitational interaction becomes strong enough to rival quantum effects. This defines the “Planck era” 10^{-44} seconds after the Big Bang, when gravitational and quantum effects were of similar strength and would require a combined theory of quantum gravity instead of the two separate theories we have today.

Nevertheless, to some physicists, c , h , and G are not truly fundamental because they depend on units of measurement. Consider for instance that c is 299,792 km/sec in metric units but 186,282 miles/sec in English units. This shows that physical units are cultural constructs rather than inherent in nature (in 1999, NASA’s Mars Climate Orbiter fatally crashed because two scientific teams forgot to check which measurement system the other had used). Constants that are pure numbers, however, would translate perfectly between cultures and even between us and aliens with unimaginably different units of measurement.

The fine structure constant α stands out as carrying this favored purity. In 1916 it appeared in calculations for the wavelengths of light emitted or absorbed as the single electron in hydrogen atoms jumps between



NOBEL LAUREATE Andrea Ghez won science’s biggest prize for her co-discovery of a supermassive black hole in the center of our galaxy. She has also precisely defined the elliptical paths of stars orbiting the galactic center.

quantum levels. Niels Bohr’s early quantum theory predicted the main wavelengths but spectra showed additional features. To explain these, the German theorist Arnold Sommerfeld added relativity to the quantum theory of the hydrogen atom. His calculations depended on a quantity he called the fine structure constant. It includes h , c , and the charge on the electron e , another constant of nature; and the permittivity ϵ_0 that represents the electrical properties of vacuum. Remarkably, the physical units in this odd collection cancel out, leaving only the pure number 0.0072973525693.

Sommerfeld used α just as a parameter, but it gained fame in the late 1920s when it reappeared in advanced work on relativistic quantum mechanics by the French physicist Paul Dirac, and then in what the English astronomer Arthur Eddington hoped would be a Theory of Everything. He planned to merge quantum theory and relativity to derive the properties of the universe such as the number of elementary particles in it, and its constants, α among them.

One twist in Eddington’s approach was that he considered the quantity $1/\alpha$ rather than α , because his analysis showed that it must be an integer as well as a pure number. This was consistent with a contemporary

It raises the notion that out of many multiverses, the one where we exist is the one with the winning value.

measurement that yielded $1/\alpha = 137.1$, tantalizingly near 137 exactly. Eddington's calculations gave instead 136, close enough to raise interest. Further measurements however confirmed that $1/\alpha = 137.036$. Eddington's attempts to justify his different result were unconvincing and for this and other reasons his theory has not survived.

But α and 137 remain linked, which is why Richard Feynman called 137 a “magic number.” What he meant has nothing to do with numerology. Rather it is that we know how to measure the value of α but not how to derive it from any theories we know. This is true also for the other fundamental constants, including pure numbers such as the ratio of the proton and electron masses, and is a lack in the Standard Model. Nevertheless, the value of α is critical in quantum electrodynamics, the quantum theory of electromagnetism. Feynman fully understood this, since he earned the 1965 Nobel Prize with two other theorists for developing quantum electrodynamics.

So α is accepted as one of the important constants of nature. Now, with the values of these quantities accurately known, physicists ask, are they truly constant? In 1937, considerations about the forces in the universe led Dirac to speculate that α and G change with time as the universe ages. Another suggestive and even older speculation is to wonder whether the constants vary across the universe. In 1543, when the Polish astronomer Nicolaus Copernicus put the sun and not the Earth at the center of the universe, he moved humanity from its special cosmic location. This implies that the universe is the same everywhere, but this is only an assumption.

VARYING “CONSTANTS” WOULD ALTER both the Standard Model and the cosmology based on it and general relativity, which among other issues fail to explain dark matter and dark energy. Add the role of α in the



Isaak Newton.

GIANT SHOULDERS This year's Nobel winners drew on astronomical techniques dating back to Isaac Newton, who wrote of scientific advances, “If I have seen further it is by standing on the shoulders of giants.”

notion that the universe is “fine-tuned” to support life and the related idea that out of many multiverses, the one where we exist is the one with that winning value of α . All this spurs research on the constants of nature, much of it focused on α .

Earthly measurements confirm that α is fixed to within parts per tens of billions. A more challenging project is measuring it over astronomical distances. This also determines α at early cosmic times, since light from billions of light-years away took that many years to reach us from a younger universe. Since 1999, John Webb at the University of New South Wales, Australia, with colleagues has been making such measurements by gathering light from the distant galactic cores called quasars where black holes pull in dust that glows. This light traverses interstellar gas clouds and is absorbed at wavelengths characteristic of the atoms in the clouds. Analyzing the wavelengths gives α at the distant location, just as hydrogen wavelengths first defined α on Earth.

Webb's early results showed that α has increased 0.0006 percent over the last 6 billion years or more, and that it depended on distance from the Earth. Results published in 2020 show a smaller change in α between now and 13 billion years ago, when the universe was only 0.8 billion years old, which the authors interpret as "consistent with no temporal change." The cumulative results also suggest that α varies along different directions in space. Overall, the experimental errors are too large to inspire confidence that any single measured change in α is exactly correct, but the changes are certainly extremely small.

Now α has also been measured within a strong gravitational field, where it can theoretically change. The strongest gravity we know comes from a black hole, where a spacecraft would have to reach the unattainable speed of light to escape. But strong gravity also accompanies a white dwarf, a star that has expelled its outer layers to leave a massive but only planet-sized core. In 2013, J.C. Berengut of the University of New South Wales, with Webb and others analyzed spectral data from a white dwarf and obtained a change in α of 0.004 percent relative to the Earth.

No one, however, had measured α near a supermassive black hole until this year's work by Hees and co-authors including Ghez. Her results from Keck helped in choosing five stars whose orbits bring them near the supermassive black hole to maximize its gravitational effects, and of a type whose spectra display strong absorption features due to the surrounding stellar atmosphere. This facilitated deriving α from the absorption wavelengths for each star. The final composite result again shows only a small change in α , of 0.001 percent or less compared to Earth.

Although the measured change in α is small, the results for five stars at different places in the supermassive black hole gravitational field led to a new outcome; they allowed an early test of theoretical predictions that changes in α are proportional to changes in the gravitational potential, the energy stored in the gravitational field. The results confirmed that the two quantities are proportional, but uncertainties in the data supported only a rough estimate of the proportionality constant. A more reliable value could select between several new theories that treat dark matter and dark energy.

The results hint at the Copernican view that on very large scales, the universe looks much the same everywhere.

For now, the measured changes in α across time and space, and under gravity, are too small or uncertain to guide physicists toward new theories or even to fuel speculation such as the prospects for life far out in the universe or near a black hole. The smallness of the changes hints at the Copernican view that on very large scales, the universe looks much the same everywhere, although more measurements could confirm that there are real if tiny differences across the universe that might be meaningful.

It may be a kind of comfort to know that in a dynamic universe, this particular cosmic number holds steady. But seeing larger changes in α near our galactic supermassive black hole could be the starting point for new physics. As Hees described in an email interview, his goal now is to get deeper into the black hole's gravitational field. He plans to carry out new optimized measurements in 2021 to "observe stars that are closer to the black hole and therefore that experienced a stronger gravitational potential ... But with current technology, it is not easy to get good spectral observations of stars that are super close to the black hole." Still, he believes he can reduce measurement errors by a factor of 10.

The world-class Nobel Prize work carried out by Ghez depended on vast improvements in observational and spectroscopic techniques. It is a good bet that further improvements building on this successful project will enhance research in the supermassive black hole, a unique arena to study those elusive changes in α and what they mean for how we understand the universe. ☺

SIDNEY PERKOWITZ is the Emeritus Charles Howard Candler Professor of Physics, Emory University. His latest books are *Physics: A Very Short Introduction*, and *Real Scientists Don't Wear Ties*. He is at work on *Science Sketches*.

Do You Know These Scientific Pioneers?

10 great minds that should have been in your science textbooks

BY TOM SIEGFRIED

IT'S EASY TO NAME science and math geniuses. I can just flip open my old book from the 1960s, which lists "100 Great Scientists"; it contains all the names you'd find on most popular lists of scientific geniuses: Einstein, Newton, Maxwell, Gauss, Bohr, Archimedes, Darwin, Galileo, and 92 others.

But the geniuses of popular notoriety aren't the only great minds of scientific history. That book and other such lists overlook many deserving names—the unsung geniuses overshadowed by more publicity-savvy rivals or underappreciated because of when and where they lived. Presented below are my Top 10 of those insufficiently recognized scientific geniuses of all time, listed in chronological order.

Keep in mind that this is science and math only, so no Shakespeare, no Bobby Fischer, no Lennon and McCartney. Also, nobody still living is eligible—wouldn't want to hurt anybody's feelings.

And remember, for list-making purposes, genius shouldn't simply be thought of as high IQ. It's more a combination of intellectual capacity and what was achieved with it. Geniuses transcend the time in which they live, contributing insights that allow future scientists to be smarter than the geniuses of the past. All the people listed here did that.



10. BRAHMAGUPTA (INDIA, 598-C.670)

A prominent astronomer, Brahmagupta wrote an extensive treatise covering such topics as the motions of the planets, eclipses, and the phases of the moon. But his genius emerged most prominently in mathematics. He introduced the idea of zero as a number like any other and discussed how to calculate with it. He was also the first to explain negative numbers, a concept thought by the Greeks to be “absurd.” Brahmagupta pointed out that multiplying two negative numbers (he called them “debts”) produced a positive number (in his terminology, a “fortune”).



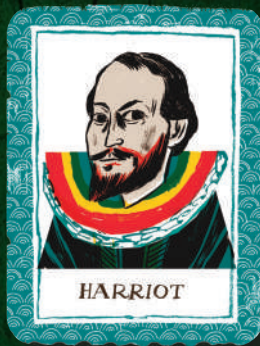
9. ROBERT GROSSETESTE (ENGLAND, C. 1170-1253)

Grosseteste was a prominent churchman who served as the Bishop of Lincoln for the last 18 years of his life. But in his earlier days he was a master of all the sciences, from medicine to cosmology. In fact, he was among the first modern scientific thinkers of the Middle Ages. He respected Aristotle but taught that experiment took precedence over authority. Grosseteste was an expert in optics, considering light to be the fundamental substance of existence; its power gave the cosmos shape, pushing matter around to form the heavenly spheres. Roger Bacon, the more widely known scientific pioneer of the 13th century, held Grosseteste in the highest esteem, while dismissing most other big scientific names of the day as dimwits.



8. NICOLE ORESME (FRANCE, C. 1320-1382)

One of the most sophisticated mathematicians of his era, Oresme worked out the logical demonstration that all observable evidence was consistent with the Earth’s rotating on its axis, rather than the sun actually rising and setting. His true genius, however, was in then stating that he didn’t really believe that the Earth rotated, so that he could keep in good standing with the church (he was a bishop) and not get put under house arrest or burned at the stake.



7. THOMAS HARRIOT (ENGLAND, C. 1560-1621)

Harriot was a master of many sciences, starting with his role as scientist for an expedition to Roanoke Island in 1585. Later in his life he became the preeminent mathematician in England, a pioneer in the establishment of algebra for both pure and applied math. As an astronomer, he observed features on the moon and spotted the moons of Jupiter, possibly even before Galileo. His works on optics included an analysis of the physics of rainbows. Most of his writings went unpublished in his lifetime; hence many later mathematicians rediscovered much that Harriot had already accomplished or foreseen.



6. ANTOINE PARENT (FRANCE, 1666-1716)

Parent applied his versatile intellect to a vast scope of scientific fields. He investigated physics and astronomy, cartography and geometry, chemistry and biology, and even music. He was most astute in analyzing practical matters such as friction's effect on motion and stresses on structural beams, and attempted to compute the theoretical maximum efficiency of machines. For his exemplar he chose water wheels, widely used to harness the power of flowing streams for such tasks as sawing wood or milling grain. Parent got the wrong answer, but nevertheless laid the groundwork for the second law of thermodynamics. Parent's harsh criticism of Descartes' science earned him no friends among his French colleagues, though, who considered Parent to be tactless and aggressive. After he died of smallpox, one obituary writer commented that Parent "had goodness without showing it."



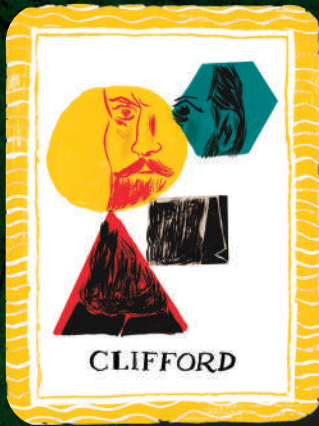
5. MARY SOMERVILLE (SCOTLAND, 1780-1872)

She was the Carl Sagan of the 19th century, one of the most respected and prolific popularizers of science of her age. Her one year of formal schooling (at age 10) triggered enough curiosity that she taught herself algebra and geometry (mostly in secret, as her father disapproved). She married and moved to London, but her husband died young, so she returned to Scotland and to science. When asked to translate Laplace's works on celestial mechanics into English, she turned the translation into a popular explanation, launching a career of writing books that conveyed the cutting edge of 19th-century science to the wider literate public. Her work, universally praised by the scientific community, combined the genius of insight with the ability to convey it.



4. ADOLPHE QUETELET (BELGIUM, 1796-1874)

As a youth, Quetelet dabbled in writing operas and poetry, but wisely switched to math, before becoming an astronomer and ultimately the most accomplished statistician of his day. Quetelet especially perceived the importance of statistical reasoning for the social sciences. He demonstrated how the prevalence of various crimes could be predicted, for instance. He also recognized the fallacies that improper statistical reasoning could propagate, noting that the numbers said nothing about any individual, but that nonetheless the statistical construction of an "average man" could reveal much about society as a whole. Also, to the benefit (or annoyance) of many dieters, he developed the formula for Body Mass Index, so that you can properly quantify how overweight you are.



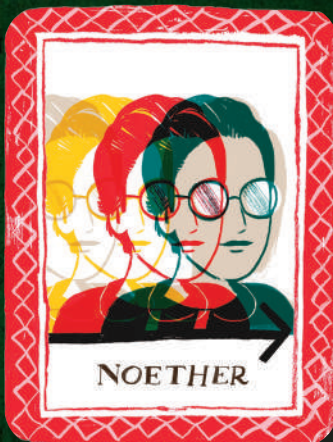
3. WILLIAM KINGDON CLIFFORD (ENGLAND, 1845-1879)

A brilliant mathematician, Clifford was in ill health for most of his adult life and died at 33. Even so he earned international reputation for his original approaches to geometry and other aspects of mathematics. His work foreshadowed aspects of Einstein's general theory of relativity; Clifford pointed out that "some or all of those causes which we term physical may... be due to the geometrical construction of our space," anticipating Einstein's description of gravity as curvature in the geometry of spacetime, the combination of space and time implied by his special theory of relativity.



2. EMILE BOREL (FRANCE, 1871-1956)

By age 11, Borel's genius was apparent enough that he left home to receive more advanced instruction and eventually made his way to Paris, where he observed that the most exciting and fulfilling lives were led by mathematicians. He became an enormously productive scholar, with major contributions to set theory (the branch of math that studies the properties of collections of objects) and probability theory. And in the 1920s he established many of the fundamental principles of game theory (the math for calculating optimum strategies)—unknown to John von Neumann, who invented them all over again.



1. AMALIE EMMY NOETHER (GERMANY, 1882-1935)

In the mid-19th century, several men figured out the law of conservation of energy, but it was Emmy Noether who figured out why energy is conserved. It's a consequence of a symmetry in nature, specifically the symmetry of time—physical law remaining the same in the future as it has been in the past. What's more, she showed that other symmetries also require conservation laws—symmetry in spatial direction guarantees conservation of angular momentum, for example. Noether contributed to many other realms of math, especially abstract algebra, and clarified some of the mathematical aspects of general relativity. Despite years of discrimination, she was eventually allowed to join the faculty at Göttingen, after the esteemed mathematician David Hilbert pointed out that the faculty senate was not a bathhouse. ☺

TOM SIEGFRIED is a freelance writer in northern Virginia and former editor in chief of *Science News*.

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When Science Was the Best Show in America

*The first US museum was devoted to truth and reason.
Then the circus came to town.*

BY LEE ALAN DUGATKIN



ON MAY 29, 1810, Katherine Fritsch, a sister in the Moravian Church, boarded a coach in Lititz, Pennsylvania, along with a group of her friends and began the 75-mile trek to Philadelphia. Fritsch noted in her diary the one city site she most wished to see: Peale's Museum. On the grounds of the museum, whose two buildings sat on State House Square, with rows of trees and manicured lawns, Fritsch passed through a menagerie that included a large cage with a live eagle sitting "right majestically on his perch—above his head a placard with this petition on it: feed me daily for 100 years."



From the yard, Fritsch went into the Peale Museum proper, through a door with “Whoso would learn Wisdom, let him enter here!” posted above. Fritsch walked past a turnstile that rang chimes to announce visitors. She walked up the stairs and into the Quadruped Room, which included a moose, llama, bear, bison, pronghorned antelope, hyena, and a jackal. She explored the Marine Room, overflowing with fish, amphibians, lizards, sponges, and corals. In the Long Room, glass cases were filled with hundreds of birds set against backdrops matching their natural environments; she saw insect cases in which the specimens could be rotated under a microscope. Fritsch didn’t get to see the museum’s mammoth skeleton, but noted in her diary that “all our talk was of how delightful had been our visit to the museum.”

Fritsch was not the only one who felt that way. From the time Peale’s Museum had opened its doors in 1786, annual attendance had averaged more than 10,000 people. Born both of science and art, it was the first true museum in the fledgling United States and the first must-see attraction not only for Philadelphians but for visitors from around the U.S. and the world. The museum’s creator, Charles Willson Peale, saw the museum as a national good. The “very sinews of government are made strong by a diffused knowledge of this science,” he wrote. The museum’s success made Peale a proud man for many years. It embodied the age

of Enlightenment in the new world. After a visit, the French philosopher Comte de Volney proclaimed the museum housed “nothing but truth and reason.” But national funding for truth and reason foundered on the shore of politics. And then the circus came to town.

PEALE WAS BORN in Maryland in 1741. When he was 9, his father, a schoolteacher, died, leaving the family in poverty. Peale was apprenticed to a saddler at age 13, but spent almost as much time tinkering with mechanical devices of all sorts as he did saddling. His other interest lay in paint brushes and sketching pads. Ambitious as could be, Peale became the Colony’s most famous portrait painter. In 1771, Peale met Martha Washington and convinced her that Colonel Washington should sit for him—the first of 25 portraits, miniatures, mezzotints, or sculptures he would do of the soon-to-be general. Peale also painted portraits of Thomas Jefferson, Benjamin Franklin, and Alexander Hamilton. He named most of his 17 children after famous painters, including Rembrandt, Rubens, and Titian.

A true autodidact, Peale saw himself as a naturalist and scientist. And any self-respecting deist of the Enlightenment should have a museum. Fortunately, Peale knew all the right people. Robert Patterson, professor of mathematics at the University of the State of Pennsylvania, gave Peale his first specimen for the museum, “a curious fish called the paddle fish caught in

Peale wrote that society raised roadblocks to women, which didn't allow them to pursue science.

the Allegheny River,” Peale wrote. Ben Franklin sent his friend the body of an angora cat that Madame Helvétius had given him when he departed Paris, and Washington sent the body of a just-deceased golden pheasant from the aviary of Louis XVI that the general had received as a gift from the Marquis de Lafayette. Other specimens soon came flooding in.

In a letter to Jefferson, Peale explained that his goal for the museum was to bring together “a variety of interesting subjects of Nature ... collected in one view as would enlighten the minds of my countrymen, and, demonstrate the importance of diffusing a knowledge of the wonderful and various beauties of Nature, more powerful to humanize the mind, promote harmony, and aid virtue than any ... yet imagined.”

Peale, a former member of the Philadelphia Militia, was a true-blooded patriot. He created an effigy of a double-faced model of Benedict Arnold in a carriage, dressed in a red coat and holding a letter to Beelzebub with the devil standing behind him shaking a purse full of money. When it came to his museum, he had no intent of curating the sort of European hall that catered only to “particular classes of society only, or open at such turns or at such portions of time, as effectually to debar the mass of society, from participating in the improvement, and the pleasure resulting from a careful visitation,” he wrote. His museum would be open to all—“the unwise as well as the learned.”

Peale held progressive views on women and children, and because he knew that a family-friendly venue would attract more visitors, he reached out to bring women and children into his museum. Women were not only encouraged to visit the museum, Peale wanted them to contribute to the enterprise, sending in samples and sharing ideas. Society, he believed, raised roadblocks to women “which allow no time for them to devote in the arduous pursuits of science,” but, he was quick to point out, “when females have devoted

themselves to these pursuits they have given every demonstration of the intensity and depth of their intellectual powers.” He wanted to tap into those powers to better the museum and the plight of women.

Reverend Manasseh Cutler, a respected naturalist of the day, who had gained fame for his bravery as a chaplain during the Revolution, was an early visitor to Peale’s Museum in 1787 and was struck by the exhibits “arranged in a most romantic and amusing manner.” He describes two dioramas—a mound with trees and an artificial pond, each the result of Peale having spent many a morning “dressing the museum in moss.” The pond was stocked with fish, geese, ducks, cranes, and herons, “all having the appearance of life, for their skins were admirably preserved.” On the beach around the pond Cutler was dazzled by an assortment of “shells of different kinds, turtles, frogs, toads, lizards, water snakes, etc.” Cutler’s diary ends: “Mr. Peale’s animals reminded me of Noah’s Ark, into which was received every kind of beast and creeping thing in which there was life. But I can hardly conceive that even Noah could have boasted of a better collection.”

From the outset, the museum was meant to be a collaborative effort. Jefferson, Hamilton, James Madison, Gouverneur Morris, famed astronomer David Rittenhouse, and naturalists Benjamin Smith Barton and William Barton, sat on the museum’s board of directors. But this museum was not to be some highfalutin society club. Peale turned more often to his fellow citizens than to his board of directors to contribute what they could, be it specimen or knowledge. Each year, he would publish dozens of newspaper advertisements that included not just a call for specimens, but lists of new specimens received of late, information about new exhibits, changes to museum hours of operation, and perhaps strangest to our eyes, praise or admonitions of the way the public was responding to activities at the museum.

A few years after it opened, in a series of parades, young boys (and older men) moved all the exhibits to the museum's new home in the American Philosophical Society's Philosophical Hall. Peale and his family moved their own home to the basement of the museum, so as to better manage the ever-growing enterprise. Soon, the museum outgrew even Philosophical Hall and moved to the State House (what we now call Independence Hall), above the rooms where the Declaration of Independence were signed, and below where a soon to be rather famous bell rang each day.

IN 1801, PEALE AND A TEAM undertook the first major paleontological excavation in the U.S. Near Newburgh, New York they dug up, and then painstakingly reconstructed, the complete skeleton of a mammoth (technically, it was a mastodon, but that distinction did not yet exist). It was quite the sight and caught the fancy of locals. "Every farmer with his wife and children, for twenty miles round in every direction flocked to see the operation," wrote Peale's son Rembrandt. The *Mercantile Advertiser* soon ran tantalizing headlines like "Bones of a Mammoth or some other Wonderful Animal," titillating readers with tales of "a monster so vastly disproportionate to every creature; as to induce a momentary suspension of every animal faculty but admiration and wonder."

In *Skeleton of the Mammoth*, a broadside that Peale posted across Philadelphia in 1802, he informed readers that though "numerous have been the attempts of scientific characters of all nations to procure a satisfactory collection of bones," he and his museum had at last done just that. Peale even had one of the museum employees distribute the broadside throughout the city while on horseback wearing "feathered dress" and preceded by a trumpeter.

Peale's team dug up enough bones to reconstruct two mammoth skeletons: the one that sat on exhibit at the Philadelphia Museum, and a doppelgänger that went on tour in England, under the watchful eyes of Peale's sons Rembrandt and Rubens. Before they left, their father gave them a bon voyage present, hosting a dinner for 13 inside the rib cage of the mammoth that was staying put in Philadelphia.

Soon a mammoth craze, arguably the first craze to sweep the country, was underway. People spoke of



THE MET OF ITS TIME Charles Willson Peale painted this self-portrait to celebrate his pioneering museum. Its goal, he wrote his friend Thomas Jefferson, was to collect subjects in nature and "enlighten the minds of my countrymen."

mammoth squashes, mammoth radishes, mammoth peaches, and mammoth loaves of bread. The *Columbia Repository* newspaper ran a story of a 1,300-pound mammoth cheese made from milking the cows of each of the 186 farmers in the town of Cheshire, Massachusetts. The cheese was sent to President Jefferson, who was delighted at what he deemed "an ebullition of the passion of republicanism."

What better time to seek federal support for the museum than with the mammoth exhibit causing such a stir and his now longtime friend Jefferson sitting in the Executive Mansion? "I wish to know your sentiments on this subject, as to whether the United States would give an encouragement, and make provision for the establishment of [my] museum in the city of Washington," as the country's national museum, Peale wrote.



TOM THUMB'S BLUES Charles Stratton (right) was a child when P.T. Barnum (left) first hired him to perform in his museum. Barnum publicized Stratton as “General Tom Thumb,” a character who became a major attraction for the circus impresario for decades.

Jefferson was understanding of his friend’s appeal for national support: This was, after all, a president who would soon be using the East Room of the Executive Mansion to lay out a few of his own mammoth bones.

“No person on earth can entertain a higher idea than I do of the value of your collection nor give you more credit for the unwearied perseverance and skill with which you have prosecuted it,” Jefferson replied, “and I very much wish it could be made public property.” But Jefferson claimed his hands were tied by Congress. “I must not suffer my partiality to it to excite false expectations in you, which might eventually be disappointed,” because many in government “denied that Congress has any power to establish a National Academy.” Disappointed, Peale accepted Jefferson’s decision, or at least told the president as much.

Peale officially retired as director of the museum in 1810, but had his hand in museum affairs for the next 17 years, until he was laid to rest at age 85. His Philadelphia Museum lived on, managed by various of his sons (and a nephew). One son, Rembrandt, opened a spinoff Peale museum—the first building in the United States that, from blueprints on, was designed as a museum—in Baltimore in 1814, and Rubens followed with another spinoff in New York City in 1825, on the very day that New York was celebrating the completion of the Erie Canal.

BY THE 1840S, the Revolutionary War generation was gone, and Americans were becoming less and less interested in the sort of entertainment offered at the Peale museums. Dime store museums, with their magicians, musicians, actors, charlatans, freaks, ventriloquists, and animal acts, each claiming to be the most marvelous of them all, were on the rise. The country had entered a period of maturity and people now had more money for leisure per se. But with so many people now living in large, crowded cities, surrounded by strangers, they were drawn to dime store museums that advertised escapism:

Come hither, come hither by night or by day,
There’s plenty to look at and little to pay...
If weary and heated, rest here at your ease,
There’s a fountain to cool you and music to please

No one understood that better than P.T. Barnum, a businessman and showman, who was a master at promoting hoaxes. In 1841, before he founded his traveling circus, Barnum opened his American Museum in lower Manhattan, all too close to Rubens Peale’s museum, and used it as a showcase for freak shows and melodramatic plays. Rubens couldn’t compete and soon closed his museum and sold the contents to Barnum. Barnum swooped in and bought out the Peale museum in Baltimore as well. In the spring of 1849, Barnum opened a branch museum of his own in Philadelphia, in the Swaime Building, a few blocks from Peale’s Philadelphia Museum. Soon Barnum wrote his partner Moses Kimball that “he’d kill the other shop in no time.” He did. The Philadelphia Museum’s last advertisement

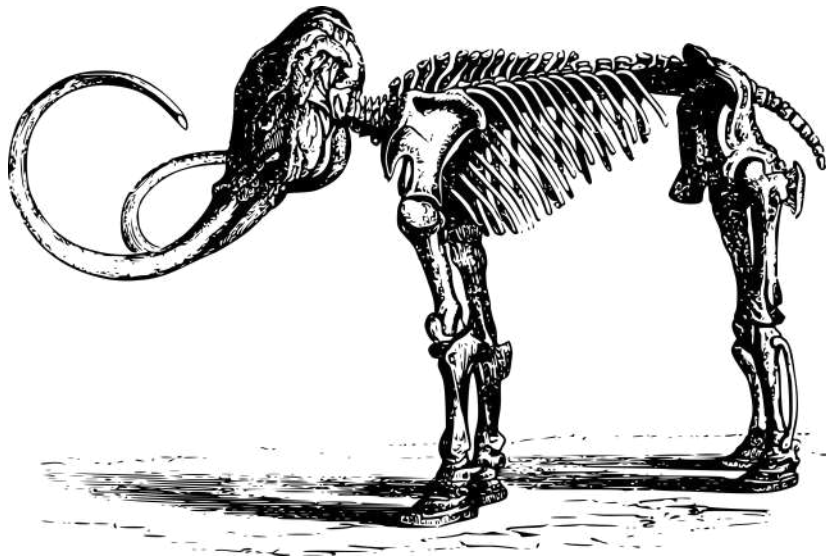
Ben Franklin sent his friend the body of an angora cat and George Washington sent a golden pheasant.

ran on Aug. 27, 1849, and soon after, the United States Bank held a public auction of all the items (aside from the paintings) in the museum. Barnum was there, and bought it all, lock, stock, and barrel.

At Barnum's American Museum, alongside many of the exhibits and fossils from Peale's Philadelphia Museum, as well as the Peale branch museums that had stood in Baltimore and New York City, the Fiji mermaid, the head and torso of a monkey sewn to the back half of a fish, was on display. General Tom Thumb, a dwarf, danced and sang in Revolutionary War regalia.

The museum attracted 15,000 people a day. Or so Barnum claimed. Nobody checked. 🌀

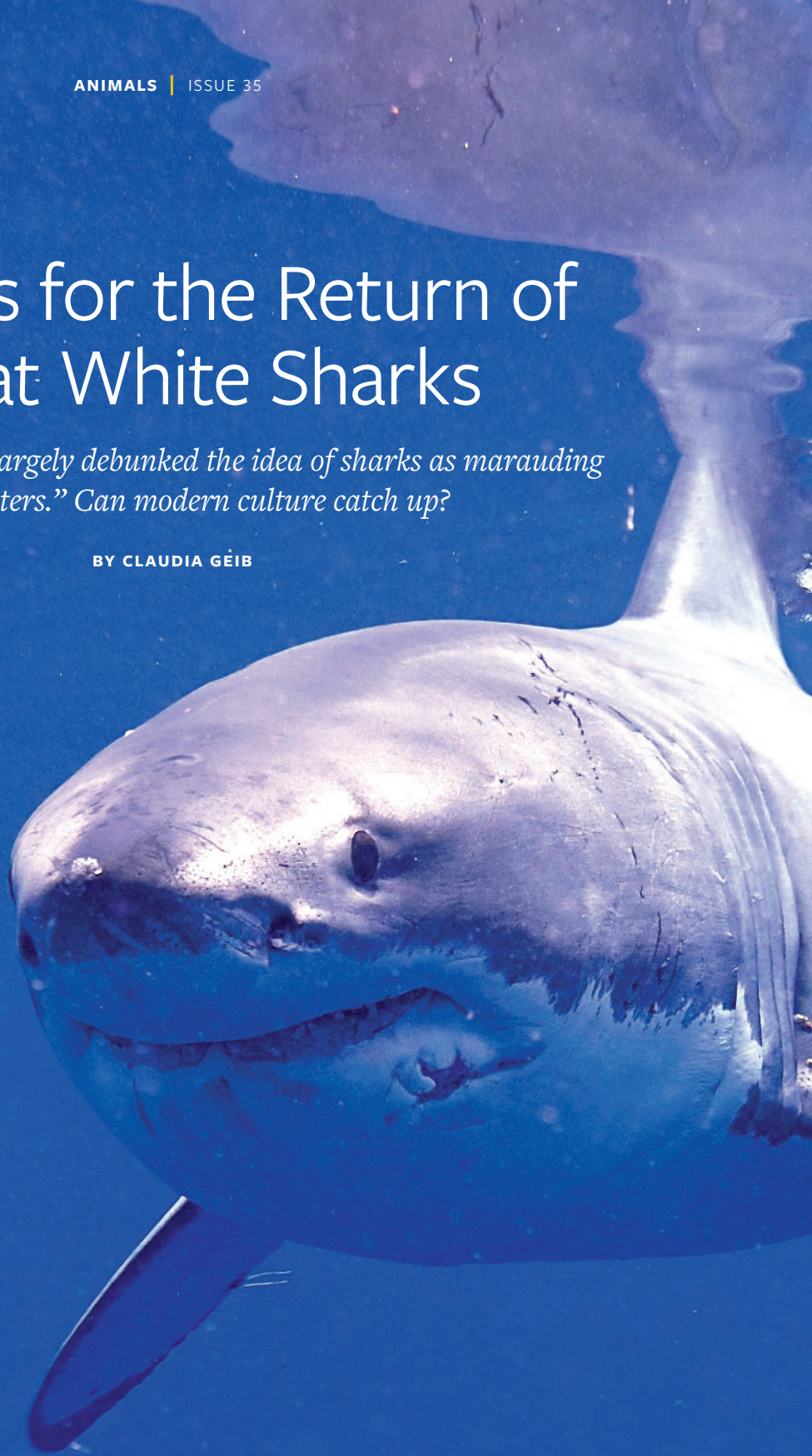
LEE ALAN DUGATKIN is a historian of science and an evolutionary biologist at the University of Louisville. He is the author of *Behind the Crimson Curtain: The Rise and Fall of Peale's Museum*, and many other books, including *Mr. Jefferson and the Giant Moose* and *How to Tame a Fox and Build a Dog*.



Lessons for the Return of Great White Sharks

Modern science has largely debunked the idea of sharks as marauding “man eaters.” Can modern culture catch up?

BY CLAUDIA GÉIB





ELIAS LEVY



IN AN OCTOBER DAY in 1849, a young writer packed up his notebooks, piled into a horse-drawn carriage, and left western Massachusetts for the outer edge of a sweep of sand known as Cape Cod. The writer was Henry David Thoreau, and over the next six years he would return here three times, forgoing the dappled shade of the woods that would make him famous in exchange for the Cape's scrubby dune plants, empty beaches, and endless sky.

In his book *Cape Cod*, Thoreau would go on to describe miles of undomesticated coast at the mercy of the sea, stunning in its mercurial moods and stark beauty. Even 150 years later, despite an influx of tourists that would have startled the sun-bleached fishermen Thoreau met, many of the writer's descriptions of the outer Cape feel strikingly familiar.

What does not is the way he writes of the Cape's sharks.

In one of the book's memorable passages, Thoreau writes of seeing a 6-foot shark swim through an area where he and some friends had just been swimming. Despite being warned by locals, the group jumped back in, seemingly unperturbed. "We thought that the water was fuller of life," Thoreau wrote, "and the expectation of encountering a shark did not subtract anything from its life-giving qualities."

It's a description that might have startled Barbara Stedman of Wellesley, who I met standing in the sand at Head of the Meadow Beach in Truro. She'd joined in on my conversation with a couple on a neighboring blanket, Tom and Jackie, when she heard mention of sharks. But when Tom noted that sharks could be found all along the Cape's Atlantic shore as well as in Cape Cod Bay, she shuddered.

"Those creeps!" she said, her face opening with shock. "That gives me something to worry about. I thought I was relaxing."

Stedman's reaction seems far more typical on contemporary Cape Cod, and throughout much of the world, than the sanguine Thoreau's. Over the last 15 years, the Cape has grappled with a steep rise in visits by great white sharks—*Carcharodon carcharias*, they of *Jaws* fame—who come to the outer Cape to hunt seals,

How our species feels about sharks is integral to their survival.

often uncomfortably close to beaches. In 2018, fear ignited when two shark attacks left a swimmer gravely wounded and a young boogie-boarder dead.

What's followed in the years since has been a feeding frenzy of a different kind, in which media attention descends on every shark sighting and beach closure on the Cape between May and November. That attention has also magnified those voices calling for measures more drastic than just closing beaches. A contingent of Cape Codders has advocated for killing sharks, or killing seals, in order to wrestle back control of these beaches.

As tragic as the events of 2018 were, I've always found this hysteria somewhat puzzling. After all, there are many places around the world, and even in the United States, that have more shark incidents and don't get the same level of media coverage. According to the International Shark Attack File, Florida leads the pack in the number of unprovoked attacks annually, with 21 in 2019. Hawaii had nine in the same year, while California had three.

On top of that, modern science has largely debunked the idea of sharks as marauding "man eaters." Most shark bites are a shark's unfortunate way of figuring out what's sharing their environment, or a case of mistaking



FISH STORY People pose beside the body of a 2,300-pounder caught near Key West, Florida, in 1956.

humans for a seal. I'd believed that people were starting to come around on sharks, both as they grasped the nature of these accidents, and as a nascent "save the sharks" movement publicized how many sharks are killed by humans every year. Did people still really want to kill more of them?

Yet beyond the headlines, there was another story: one of ecosystems and communities in flux, and one that fits a pattern identified by social scientists in other "sharky" places. Research from around the world suggests that humans not only *can* live with our toothy neighbors, but that in many places, we've already started to. The fearful narrative we are all too familiar with doesn't appear to be coming from communities themselves, but from the politics and news coverage that surrounds attacks.

The implications of that disparity stretch well beyond the sandy edges of tourists' beach vacations. Sharks of all sizes are essential to the health of ocean ecosystems, but overfishing, climate change, and habitat destruction are winnowing their populations

worldwide. With so many of these species sharing the shallow coastal waters we humans enjoy, how our species feels about sharks is integral to their survival.

In other words, saving sharks relies less on trying to change the shark's ancient behaviors, and more on finding our inner Thoreau: in changing our own way of thinking about them.

AMONG THE VARIED CROWD of its year-round residents, Cape Cod has a long and much-argued tradition of distinguishing between those who were born here, and those who moved here. According to these unwritten rules, only those born on the peninsular side of the Cape Cod Canal get to wear the official title of "Cape Codder." The rest of us are all "wash-ashores," whether residents for one year or 80 years.

But how about 450 million?

That's when the very first sharks arose, evolving around 200 million years before the dinosaurs and outliving them all. As scores of land species rose and fell, sharks swam coolly through asteroid strikes, five



DINNERTIME A white shark (silhouette, top right) swims near a pack of gray seals off Lighthouse Beach in Chatham, Massachusetts.

mass extinctions, five ice ages, and all of the dramatic global warming in between. When a glacier carved the arm of the Cape on its retreat northward, between 14,500 and 15,500 years ago, the modern great white shark had already been around for between 6 and 8 million years.

All of that changed in the late 1800s, when the northeastern states of Maine and Massachusetts set off a seal-killing spree by paying bounties for seal pelts in a misguided attempt to protect local fisheries. By the time these bounties ended and the 1972 Marine Mammal Protection Act took effect, gray seals had been exterminated south of the Canadian border. Only a few hundred harbor seals remained in Massachusetts. One 2009 paper estimated that between 72,284 and 135,498 seals had been killed.

Around the same time, people stopped spotting great white sharks, also known simply as white sharks, as well. Some of this may have been because they moved further offshore, switching to fish and whales from seals. But the great white population itself also declined in the northwestern Atlantic through the 1970s and 1980s. Shark fishing was then unregulated, and a growing U.S.-China relationship built an American trade in shark fins and meat that still exists, albeit in a more sustainable form, today. Research suggests that the population decreased by as much as 86 percent over two decades, bottoming out around 1988.

And of course, you can't talk about great white sharks without talking about *Jaws*. The 1975 movie inspired the creation of shark fishing tournaments worldwide, where thousands of fishermen headed in search of a trophy great white of their very own. The effect of this

recreational fishery remains unquantified but is thought to have played a role in white shark declines.

Both commercial and recreational fishing for great whites was banned outright in 1997. Not long after, populations started to rebound, just as seal populations hit their stride again. Starting in the early 2000s, commercial vessels began reporting white sharks attacking fishing gear. Seals started showing up dead or injured on shore, missing large bits of themselves. People began seeing the attacks on seals firsthand, in bloody, thrashing spectacles not far from shore.

For ecologists, it was an incredible success story. Sharks of all sizes are a vital piece of natural ocean ecosystems, both as predator and prey. And while half of shark species are less than 3 feet long, larger sharks like great whites play an important regulatory role: They eat sick and injured fish, leaving the healthiest to reproduce, and prevent any one group from becoming overpopulated. Just their presence can shape an ecosystem; one 15-year study in Australia showed that with tiger sharks nearby, dugongs, dolphins, birds, and sea turtles chose to eat elsewhere, in turn influencing the distribution of keystone plants like seagrass.

Yet catch reports suggest global shark populations may have decreased by at least 20 percent worldwide just in the last two decades, with much more dramatic declines in some places—up to 99 percent for some species in the Mediterranean. An estimated one-third of all shark species are at risk of extinction. In such a world, the white sharks' return to the north Atlantic signaled both that species conservation worked and that their ecosystem was healthy enough to support them.

We're having to consider living in a world that's not completely dominated by human choices and preferences.

However, experts knew it was only a matter of time before these returning sharks started interacting with humans. As unlikely as a shark bite is to an individual—statistics famously remind us that you're much more likely to be struck by lightning, crushed by a vending machine, brained by a coconut, or mauled by your neighbor's dog—Cape Cod had both a lot of seals and a lot of humans in the water.

The first came in 2012, when a white shark bit swimmer Chris Meyers in Truro. After a quiet spell, 2018 saw the attack on William Lytton, just 10 miles south of the spot where I spoke to Barbara Stedman, and the death of Arthur Medici. To the community, this did not feel like a success story; it felt like there were intruders in the backyard, and those intruders had 5-inch-long serrated teeth.

The trauma that communities in the outer Cape felt after Medici's death was very real. With it, however, came sometimes another feeling: that the risk Medici faced in the ocean that day shouldn't have been allowed in the first place. Here, Cape Codders' views were shaped by "shifting baselines," or the tendency to assess our environment according to recent memory.

"The human lifespan shapes our baseline," explained Catherine MacDonald, a researcher at the Field School Miami who studies sharks and shark-human conflict. "This is a wonderful success story from an ecological health perspective, but people feel like [the sharks] don't belong there because they weren't there when they were younger." To those people, living with sharks can feel like they're being asked to assume a new and unusual risk. "In fact," said MacDonald, "we're kind of having to consider the possibility of living in a world that's not completely dominated by human choices and preferences."

Perceived risk and those shifted baselines can produce some drastic ideas. Here on the Cape we've heard stirrings of interest in lethal methods of shark control, most famously from vocal Barnstable County Commissioner Ron Beatty, who called for a great white cull after

Medici's death. In the years since, he's also advocated for culling seals, a concept some fishermen (echoing their 19th-century predecessors) also support to "protect" fish stocks. Indeed, every time this concept is raised, news reports find everyday Cape Codders—fishermen, surfers, snowbirds, and year-rounders alike—who support it. But it's difficult to establish how widely-held this sentiment really is.

Indeed, suggestions for Cape Cod's shark "problem" have ranged widely, from creating barriers out of bubbles or kelp, to wearable electromagnetic devices for surfers and swimmers, to giving seals birth control. If there's a trend in all of these solutions to the shark "problem," it's that they focus on actively shaping the natural world to fit human needs.

The world of social science offers a surprising alternative. Some research suggests that what humans need is not to re-tool the environment, but to become more intimately acquainted with it. In other words, humans don't need fewer interactions with sharks, but instead more of them.

LIKE MANY OF THE SHARK SCIENTISTS I've spoken to, Christopher Pepin-Neff describes his childhood self as "a shark kid," from the pile of books he kept next to his bed to the shark cut-out he pasted on the wall.

What's unusual is that Neff is not a biologist or an ecologist; he's a social scientist. A senior lecturer at the University of Sydney, Pepin-Neff has spent the last decade looking into the laws, politics, and media that surround sharks and shark bites. He's even received death threats, as his work often runs counter to beach protection measures that give locals a sense of security. But he was surprised when he started calling people after shark bites.

"Even in the face of the worst press sharks could get for 20 years, the public still doesn't blame the shark," Pepin-Neff found. "No one is telling this story, and yet the public still totally gets it."

This disparity between public views and government actions results in a battle for our imaginations.

That revelation came from studies in Cape Town, South Africa, and in East and West Australia, where Pepin-Neff surveyed community members before and after a shark bite occurred nearby. In all three locations, there was no statistically significant change in people's pride in having sharks in their environment, nor in their confidence in local efforts to protect swimmers. In both Australian towns, Pepin-Neff also tested if people were more afraid of sharks after attacks, and again found no significant difference.

Pepin-Neff can't definitively say why the people he surveyed have such tolerant attitudes toward sharks, but another of his experiments may provide a clue. In surveys performed at the Sydney Aquarium, Pepin-Neff had visitors describe their feelings about sharks before and after walking through the aquarium's shark tunnel, where they were surrounded by fins and teeth on all sides. One-third of them were primed to consider the sharks' intentions: They were asked how good the sharks' eyesight was, whether they thought the sharks could see them, and whether they thought that sharks in the wild tended to avoid humans. Another group received a science-focused message that focused on the statistics of shark bites. A control group received no message at all.

Remarkably, all of the people surveyed reported being less afraid of both sharks and shark bites upon leaving the shark tunnel than when entering—and those who had thought about the sharks' intentions displayed greatest reduction in fear. It seemed that seeing sharks, and particularly gaining a better understanding of them, seemed to make people less afraid.

These findings also jibe with the experience of scientists and educators elsewhere. Take Cape Town,

where in 2004—following a handful of shark bites in less than a year—an organization called Shark Spotters started placing lookouts on coastal mountains. They set off an alarm whenever a white shark is seen close to shore. According to Sarah Waries, the Shark Spotters founder, knowing that sharks are frequently close to shore, yet doing no harm, has changed the way the community responds.

Previously, any alarm would clear the beach for the rest of the day. “Now we set the siren off, they wade out of the water, and they get irritated and ask us, ‘How long is the shark going to be here?’” said Waries. “And then they go straight back in.”

“There is a mythical public attitude that people don't like sharks, or that people take it out on the shark” when someone is bitten, said Pepin-Neff. This is the classic *Jaws* narrative: that marauding sharks must be hunted down to ensure community safety. In 2004, Pepin-Neff documented how this very narrative was used, following a series of bites, to support shark hunts in Western Australia despite public opposition.

This work has led Pepin-Neff to conclude that politicians and news reports are more to blame for this bloodthirsty narrative than the public, or the shark itself. “If you want to look for someone who is manipulating the public for their own political benefit to maintain power, when something terrible has happened, that's politicians,” he said. Media, he added, exacerbates this by tending toward sensational language, such as saying a shark is “lurking” around a beach.

This cycle can spur governments to oversteer in their response, enacting policies with the greatest apparent effort in order to prevent political backlash. For example, after a series of shark bites in Western Australia, the government adopted a practice of killing any large shark over 3 meters in length caught on baited drum lines—hooks attached to a floating buoys that are fixed in place by an anchor—near beaches. The practice ended in 2014, though the government reserved the right to reinstate it.

In Queensland, Australia and KwaZulu-Natal, South Africa, lethal nets and drumlines have been standard practice for decades. Recent policy changes in both locations require that any animals found alive, sharks included, are supposed to be tagged and re-released. However, many animals die before this can happen.



SAVE THE SHARKS Protests against the Western Australian government's shark cull in 2014.

Between 2013 and 2017, an average of 83 percent of sharks and 55 percent of bycatch animals, like dolphins and turtles, died in KwaZulu-Natal's nets and on its drumlines.

These lethal programs not only harm marine ecosystems. It's also unclear if they make humans safer. The Queensland and KwaZulu-Natal governments both credit their programs with preventing fatal shark incidents. However, a 2019 review of Queensland's program suggested that increased beach patrols and improved emergency responses played a much larger role. The West Australian drumline program targeted great whites, believed responsible for the prior attacks, but didn't catch even one—and instead hooked many other species as bycatch. Elsewhere, a review of the shark culling program in Hawaii between 1959 and 1976 found that the culls didn't change the rate of local shark attacks.

This disparity between public views and government actions results in a battle for our imaginations.

The sources of information that we are supposed to trust appeal to emotion: They tell us that sharks are enemies to be repelled from the gates. Yet our own experiences appeal to logic: When we have time to interact with sharks, and with their environments, we understand their intentions are not those of targeted killers, but simply wild animals.

MacDonald, of the Field School, likened the effect to how routine interaction with cars teaches us not to fear driving despite the potentially grave risk it poses. "Most of us don't have the kind of relationship with sharks, where we have many benign interactions with them," she explained, before qualifying herself: Many people do in fact have interactions with sharks, "but we hardly ever know about them." In the wild, most sharks remain nearby but unseen, minding their own business.

All this suggests that, when it comes to coexisting with sharks, what Cape Cod may need is akin to exposure therapy. The bad news is that, like any form of therapy, changing the way you think takes time as well



I SPY A Shark Spotters post at Kogel Bay near Cape Town, South Africa.

though that doesn't stop my imagination from summoning them. Gray seals' favorite way to relax appears to be bobbing, like buoys, heads just poking above the water, and in this pose their triangular noses look surprisingly similar to dorsal fins.

as effort. You have to ride the roller coaster repeatedly to learn it won't hurt you. Yet it's important that Cape Codders, and humans more generally, take this ride.

If our relationships with sharks are no longer dominated by fear, programs like culls should cease to be a reflexive response to potential conflict. People might also be more attentive to other actions and policies that affect sharks, such as fishing bycatch, climate change policy, and the creation—or dissolution—of marine protected areas. We might better see the ocean not as a resource for our utilization, but as it truly is: as the edge of an alien nation, where humans are never much more than visitors for whom evolution packed the wrong suitcase.

ON A PEARLY GRAY MORNING in mid July 2020, I set off walking up the Cape Cod National Seashore in search of the animal I'd spent so much time talking and thinking about. I'd been told about a spot just up the beach from Head of the Meadow where seals like to congregate. I figured if there's anywhere I might see a shark, it would be here.

After about 20 minutes of walking, I found them: a congregation of nearly 100 gray seals, bobbing less than 10 feet offshore. Their heads turned in sync. Enormous black eyes tracked me as I plopped down on shore.

Gray seals, it turns out, spend most of their days in supreme repose. They mostly loll in the surf, groaning in voices that can sound eerily human on the breeze. Occasionally, a few band together to corner schools of young striped bass against the shore. No sharks arrive,

The sharks' presence was very real out there—much more real than it was when I was writing about them from my house on the Buzzards Bay side of the Cape, which is warm and seal-free and rarely, if ever, sees a great white. I find my pulse is up, my senses sharpened. I'm keenly aware that over the last few weeks the Atlantic White Shark Conservancy has logged dozens of sightings on this coastline, including a few off this very beach. As time goes on, I'm increasingly unsure what I would do if a shark did arrive.

It brings to mind an apt comparison: A friend once said that the way we humans feel about sharks is not so different from how we feel about other large predators, like wolves and bears. We love the concept of them, cheering as they slice across our screens during Shark Week, or howl with unbridled freedom at the moon in movies, or splash playfully after salmon in glossy magazine photos. But when these predators stroll or swim into our own environs, our feelings about them get a little more complex.

"Sharks are definitely making it into the news, but people still have a lot of questions," explained Marianne Long, education director at the Conservancy, a Cape-based white shark research and education nonprofit. The organization recently started a beach education program, dubbed Shark Smart, that places volunteers on local beaches to answer questions. Throughout the year the organization also runs talks and workshops that draw hundreds to learn about "Living With White Sharks," as one recurring event is called. During the coronavirus pandemic, talks have gone online.

“We’ve morphed from a society believing the only good shark was a dead one to knowing that we need to protect these animals.”

As they begin to grapple with sharks’ permanent new presence, many outer Cape towns are doubling down on education and outreach. Lifeguards are trained in shark behavior and how to advise beachgoers on shark-smart habits. Guards learn specific “stop the bleed” practices for bites, and the Conservancy teaches the same techniques to the public. On remote beaches, towns have started stocking kits with special bandages and tourniquets to address heavy bleeding. Some beaches are adding 911 call boxes and cell signal boosters, to compensate for the poor service in the area.

Meanwhile, the understanding that Pepin-Neff documented in Australia and South Africa is already beginning to shift on the Cape.

“In general, I’ve seen a massive evolution in thinking when it comes to sharks,” said Greg Skomal, a senior fisheries biologist with the Massachusetts Division of Marine Fisheries and the de facto expert on great whites around the Cape. While his professional focus is on satellite-tagging great white sharks and trying to learn more about their lives, Skomal dedicates some of his remaining time to teaching lifeguards, officials, and the public alike, by holding workshops and public talks on coexistence.

“Over the course of my 35 years doing this, I think we’ve morphed from a society believing the only good shark was a dead one to knowing that we need to protect these animals, or at least manage them sustainably,” he said.

Many tourists at Head of the Meadow echoed this sentiment. Most told me that they wouldn’t risk swimming far from shore, but despite that fear, recognized that the ocean was a wild place.

“It’s their ocean, it’s where they live,” said Julia Jolliff, who was visiting from Ohio with her husband and three sons. “And I’m sure some people don’t like

it, you know they can’t swim as much or surf or whatever. But I think figuring out how to live with them is totally important.”

Skomal noted that there will always be some people who resent sharks’ presence. For the surf shop or bed-and-breakfast who sees bookings drop off after

a bite, he understands where they’re coming from. But Skomal, and many of the shark experts I spoke to, agreed that communities learning to live with sharks simply need time to let that exposure therapy take effect. That’s why it’s so important to have shark education programs in these communities, said Sarah Waries of Cape Town’s Shark Spotters, even if the risk of a shark bite remains relatively rare.

“Shark bites cause psychological trauma for the whole community, even for people who don’t use the beach regularly,” Waries said. She remembers, following a spate of bites in Cape Town in the early 2000s, when beachfront coffee shops were struggling to find customers, and lifesaving groups couldn’t get anyone to sign up for guard training. Even if the actual risk is low, community fear still needs to be managed.

I spent more than an hour watching the seals before admitting to myself that the odds are probably not in my favor. As the sun starts peeking through the clouds I gathered my sneakers and my sopping backpack, ambushed by the incoming tide. I headed back along the frozen wave of dunes.

Walking along the seashore, it’s still easy to imagine yourself back on Thoreau’s Cape Cod. Out here there’s nothing but the breath of the Atlantic, the call of gulls, and the endless shoreline; in my time with the seals, I see only two other people.

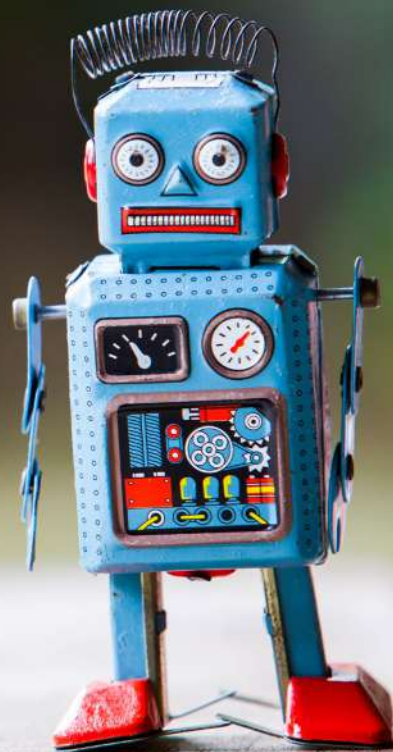
This timeless feeling is, after all, what draws many people out to this improbable spit of sand. If people have learned to love that, perhaps they can love the wild ocean that comes with it—sharks and all. ☺

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Toys Are the Future of Philosophy

Playthings shouldn't confine kids but allow them to ask, What if?

BY JONATHON KEATS



HAVE BEEN WANTING to do this since I was 5 years old,” Apple CEO Tim Cook proclaimed to a packed San Francisco auditorium on March 9, 2015. “The day is finally here.”

The standing ovation that Cook received as he announced the arrival of the Apple Watch, and revealed that he could make phone calls through a miniature microphone and speaker, showed that many techies shared his childhood fantasy. Lest anyone fail to recognize the origin of this collective dream, media outlets far and wide touted the product launch as the long-awaited debut of the two-way wrist radio, famously worn by Dick Tracy, the most celebrated comic strip detective of the 20th century.

In truth the wrist radio had been available since 1947, just one year after the cartoonist Chester Gould outfitted his undercover cop with the iconic gadget.

In a comic book advertisement, a New York electronics manufacturer called Da-Myco offered “the most amazing invention you’ve ever seen” for \$3.98 postpaid. Although the Da-Myco product lacked the fictional gizmo’s 500-mile range—and the diminutive crystal radio had to be hardwired to other units in order to communicate with them directly—it was “not just a dream ... but a scientific reality”: an early-stage communications technology that allowed children to play out the future foretold in the comics.

The Dick Tracy two-way wrist radio is one of countless toys from the 20th century that prophesied the world in which we live today. Although many of these

futuristic playthings anticipated technological innovations and societal changes that have not yet come to pass—and might never arrive, especially if laws of nature stand in the way—each product has given older generations significant influence over younger ones by setting expectations.

Futuristic visions have a powerful effect on children's imaginations. Futurists often say that these visions “colonize the future,” analogous to the colonization of continents belonging to other peoples. But unlike encroachments on indigenous territory and native autonomy, which are never defensible, premonition can potentially be a gift, nurturing new ideas and helping to set priorities in advance.

Back in 1991, when Apple was still just a desktop computer manufacturer, University of Arizona archaeologist Michael Brian Schiffer wrote a book titled *The Portable Radio in American Life*, in which he coined the term *cultural imperative* to describe “a product believed by its constituency to be desirable and inevitable, merely awaiting technical means for its realization.” The examples he cited included the television—which had entered the consumer marketplace largely because RCA president David Sarnoff was convinced of its desirability and inevitability—and Dick Tracy’s signature communications device. “The Dick Tracy radio and other radio toys introduced young Americans to the expectation that radios would become ever more portable,” Schiffer argued in his book, a claim he might have made about phones a decade-and-a-half later. The cultural imperative, with its cultish tone, could hardly have found more vivid expression than the standing ovation Cook received in 2015.

Chester Gould’s wrist radio communicated its imperative all too clearly. The question for visionary artists, innovative toy makers, and responsible parents is how to avoid cultural imperatives that colonize the future. Instead of purporting to show kids what the future will bring, futuristic toys need to ask children what kind of future they want.

AT THE END of the 19th century, a British clerk named Frank Hornby invented a new way to keep his boys entertained. Observing how cranes on the Liverpool loading docks were made with interchangeable parts, he designed a set of miniature girders and wheels that

Instead of showing kids what the future will bring, toys need to ask what kind of future they want.

could be fit together in myriad configurations to make numerous machines and structures, from tractors to towers. Initially called Mechanics Made Easy and later shortened to Meccano, his kit was the first industrial construction set for kids.

Meccano rapidly became an industry unto itself. Offering numbered construction outfits, each sequentially larger yet all designed to fit together, and a series of instruction books showing ever more advanced projects, Hornby successfully created a proprietary system through which children literally and figuratively engaged the engine of capitalism.

The purpose of Meccano was unabashedly didactic, a position reflected even in Hornby’s 1901 patent for “improvements in toy or educational devices.” In marketing materials, the product was presented as a sort of apprenticeship-in-a-box, teaching “correct” engineering principles that competing toys purportedly failed to demonstrate. Or as Hornby phrased it himself in an early biography written for his core audience of boys, “you are building for the future.”

This message was paradoxically reinforced by Hornby’s own identification with the past—he immodestly compared himself to James Watt—and by his efforts to anchor Meccano in the present. *Meccano* magazine, a periodical that published Meccano instructions and advice for “Meccano boys,” regularly featured technical devices made by grown-ups with Meccano components. Ranging from microtomes for microscopy to differential analyzers for ballistics calculations, these mechanisms took advantage of the convenience and versatility of metal parts pre-cut in standard sizes. One implicit lesson was that everything could be made in this way. Another was that this way of making things was inevitable in the future because it was



already happening and had been since the dawn of the Industrial Revolution. As with the Da-Myco wrist radio—and later versions of the Dick Tracy toy made by Remco and the American Doll & Toy Corp.—the “scientific reality” enhanced the technophilic promise of a world in which man could do anything with enough mass-produced girders and bolts.

The impact of this promise can be seen in the world today, as can the limitations of Hornby’s industrial-strength vision. Prominent architects including Norman Foster, who designed the Hong Kong and Shanghai Bank Building, claim to have been inspired by Meccano. The architect Richard Rogers has even more directly engaged Hornby’s invention by making models for buildings out of Meccano parts. And he and Renzo Piano described their most famous building, the Centre Pompidou in Paris, as “a giant Meccano set” in a statement they published in *Architectural Design* in 1977, the year that construction was completed.

On a superficial level, the comparison is apt. But the colorful struts that gave the Pompidou its distinctive Meccano look had to be custom made to the architects’ specifications at extraordinary cost. Even the modularity of the building touted by Rogers and Piano—which they contrasted with the “static” quality of traditional architecture—has proven to be more hype than reality.

“TRACY HERE” The comic book hero’s two-way wrist radio enchanted kids and prophesied the world today.

As Oxford Brookes University architectural theorist Francesco Proto has noted in *The Journal of Architecture*, “the ideological perception of the building exceeded the real possibilities suggested by its hyper-flexibility.”

The engineering principles taught by Meccano may have been technically correct, but they were not always applicable to the realities of modern industry. Nor were they always amenable to maintenance of a shiny new museum in a dirty old city. On the most banal level, the placement of heating and ventilation ducts on the exterior of the building has created a needless impediment to washing the windows.

By engineering standards, the Pompidou is far less practical than many buildings that make no allusion to Meccano. Engineering problems are not all interchangeable. A system of interchangeable parts is not universal. Good engineering depends not only on what is possible but also on what is appropriate.

Ironically Meccano limited the imagination of children who played with it because it gave the illusion of being unlimited. Hornby excluded all non-industrial answers to the question of how to build for the future, an omission that has become more obviously problematic as we have witnessed the ecological devastation wrought by industry. If the Dick Tracy wrist radio introduced a cultural imperative, Meccano presented an operational mandate. The future can be occupied by what children want to have and also what they expect to achieve.

IN 2002, THE SOCIOCULTURAL ANTHROPOLOGIST Jean-Pierre Rossie traveled to the Anti-Atlas Mountains in Southwestern Morocco to study children’s play habits. A local schoolteacher he met gave him some toys made by students several years earlier, including a cellphone crafted in clay by an Amazigh child who was 6 or 7 years old at the time of fabrication. Over nearly a decade, Rossie accumulated more examples, made by both boys and girls. He also collected toy televisions and cameras made out of scrap materials. These were

similar in their style of craftsmanship to much older toys from Morocco, and also consistent with the older toys' imitation of real objects, but they differed in one important respect. "[T]he inspiration for [children's] pretend play comes today more than in the past from situations and information that are not solely related to local life, but seep into the child's world through television and tourism," Rossie observes in *Technical Activities in Play, Games and Toys*.

What is found in Morocco has parallels throughout Africa. Handmade toy cellphones and electronics are seen in Mozambican villages and Ugandan refugee camps. They are artifacts of globalization, reflecting media saturation and cultural homogenization. However they can equally be interpreted as bottom-up expressions of children's wishes. In other words, African children's futures may be colonized by TV networks and tourists, and the urge to catch up with the "developed" world, but these boys and girls are exploring the developments they anticipate and want with their own hands. Their self-directed inventiveness with mud and recycled materials makes their perceptions of the future malleable. Their surroundings are their Meccano.

In fact, Meccano and other building kits could benefit from observation of these children's play habits. Instead of developing closed systems with ever more pieces—the Hornby model, subsequently mastered by Lego—they could approximate true universality by opening up to the whole universe.

A first approximation of that alternate reality—one in which the benefits to children override corporate profit margins—was created in 2012 by the artists Golan Levin and Shawn Simms. Their Free Universal Construction Kit is a set of 80 blocks that allow children to connect parts from 10 popular construction sets, including Lego and Tinker Toys. The blocks are freely distributed as digital files that anyone can output on a Makerbot. Of course the Free Universal Construction Kit is totally unauthorized. As Levin noted in an audio tour for a 2015 Museum of Modern Art exhibition where the blocks were exhibited, "the kit is not a product, but rather it's a provocation."

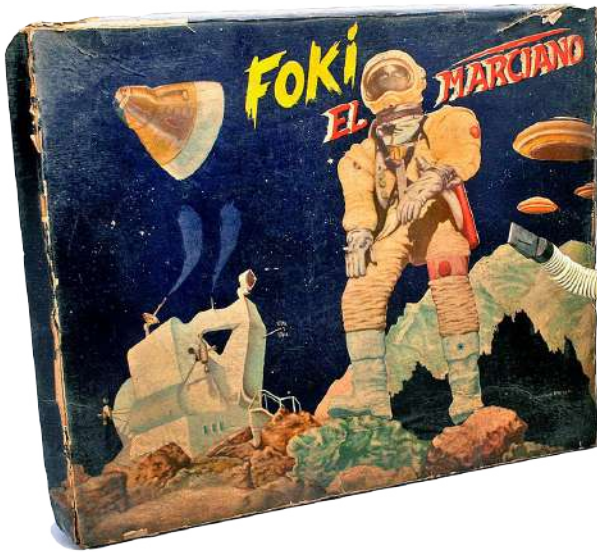


CAPITALISM FOR KIDS Meccano, the toy engineering kit, was the first industrial construction kit designed for kids.

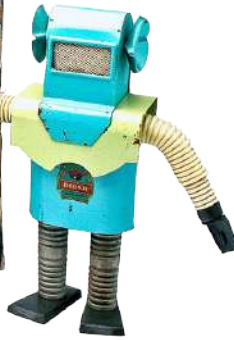
Taking away mass-produced toys outright might be one way to achieve that goal.

Why not take the provocation to the next level? To rupture the internal logic of these toys, and to deflate the operational mandate of industrialization, requires more than just offering interoperability. For children to build their way toward all possible futures, they need to be able to choose the building paradigm.

Taking away mass-produced toys outright might be one way to achieve that goal. The creativity of children in Moroccan mountain villages and Ugandan refugee camps is induced by the paucity of consumer goods (as becomes evident with their abandonment of mud and found materials whenever consumer goods become available). But it's hard to imagine much popular support for a Luddite Ebenezer Scrooge. And in any case, toys have the capacity to inspire children, not only to confine them.



I, ROBOT Foki, the toy robot, opened kids' minds to asking what sort of relationship they wanted to have with future technology.



Gross had recently played a pivotal role in World War II, inventing the first battery-operated ground-to-air radio, which the Joint Chiefs of Staff would later credit with “saving millions of lives by shortening the war.”

But he was more well known at the time for having invented the walkie-talkie, which had originated with his teenage fantasy of operating a HAM radio on the go. He patented his walkie-talkie in 1938, at the age of 20, and was tinkering with a wrist-size version when Gould came calling.

Gross wasn't a man to follow a cultural imperative. His name does not appear in Schiffer's book, and there is no historical evidence to suggest that he was trying to fulfill the vision of a pocket radio that Schiffer meticulously traces back to the publisher Hugo Gernsback in the first decade of the 20th century. Instead Gross innovated in a playfully open-ended way. He patented a pager, an automatic garage door opener, and a cordless phone, none of which found a market in his time. “If I still had the patents on my inventions, Bill Gates would have to stand aside for me,” he quipped to the *Arizona Republic* near the end of his life. Gross's inventions have less in common with products than with philosophical instruments, each begging the question *what if?*

The answers were often telling. When Gross brought his newly invented pager to a Philadelphia medical convention in 1949, doctors responded in horror that it would interrupt Sunday golf games. What might have seemed laughably shortsighted at the time was actually prescient. Provoked by the prospect of beepers on their belts, the doctors anticipated the downside of 24/7 availability—and divined the Pyrrhic victory achieved by Apple with the apotheosis of the smart watch.

What if kids were invited to play-test emerging technologies, initially introduced as toys?

The ideal Meccano set would actively challenge children to prototype possible futures beyond anything they've seen or their parents could imagine. A hybrid building paradigm could inspire genuinely novel experimentation by children. Imagine a kit that combined the logic of how industrialists build with the way nature does. Imagine the models that could be built, where portions would be bound together with bolts and parts would be grown from seeds.

IF CHESTER GOULD was a Meccano boy, history does not record it. He certainly never tinkered with wrist radios himself. The idea for Dick Tracy's favorite gadget originated when Gould visited the inventor Al Gross in the winter of 1945.



CHILD'S CLAY Handmade cellphones from African villages are artifacts of globalization but can be interpreted as expressions of kids' wishes.

What if futuristic toys were to ask *what if?* What if they were presented as possibilities instead of selling themselves as desirable or inevitable? What if the possible futures they represented were multiple and divergent? This has happened inadvertently in the case of toys that have been constrained by manufacturing limitations. In the late 1960s, an Argentine home appliance manufacturer called Daisa made a toy robot called Foki that was supposed to be an artificially intelligent android of extraterrestrial origin but bore closer resemblance to a reconfigured vacuum cleaner. Foki presented children with a sort of cognitive dissonance that arguably opened their minds to asking what sort of relationship they wanted to have with future technology.

But what if the cognitive dissonance were deliberate? Or what if children were invited to play-test emerging technologies, initially introduced as toys, instead of being handed their parents' cultural imperatives?

Playthings don't have to play that old game. Toying with tomorrow, children can co-invent the future in the here and now. ☺

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What Did the Past Smell Like?

Get a whiff of a new sensory experience in history

BY ANN-SOPHIE BARWICH

WHEN PEOPLE ENTERTAIN themselves by transporting to the past, 19th-century Berlin, say, they don't often imagine a dramatic shift in smellscape. The inhabitants talk differently. Their fashion looks strange. But what do those streets smell like? Suddenly, it hits you—a texture of reality carried by a strong whiff of ... horse manure. It may very well be that, among all your sense organs, your nose would register the starkest change.

Even so, it's a tricky thing to pin down smellscape of the past. Smells are notoriously fickle. They are not suited for permanent capture or easily imagined. Odors are caused by airborne compounds emanating from materials. The moment you open a perfume bottle it releases the very volatiles of which it is composed. (A museum of historical perfumes would come to a foreseeable end if it adopted an open-bottle policy.) That's why the sensory recreation of history presents an intriguing scientific challenge¹: How do we know whether we've succeeded?

That's a question with which the minds behind "Odeuropa" will have to grapple. Launching in January 2021, it is a \$3.3 million, three-year, multinational project on the collection and recreation of smells in 16th- to early 20th-century Europe that will marry historical and literary analysis with machine learning and chemistry. The project is pioneering and also, in a year of COVID-19 induced anosmia with sensory-deprived lockdowns, timely.² We became aware of our need for environmental stimulation—and the undervalued power of smell.

The difficulty is that descriptions of past scents are people's stated impressions. Labels express conceptualizations. They are not the same as perceptions. They also may not tell us specifically what materials were present. As horticulturalists know, a rose by any other name consists of hundreds of different volatiles and miscellaneous fragrant notes. The smells of Bulgarian roses are not the same as the roses in Kew Garden London.

Descriptions of odor also are culturally mediated.

A 2016 study showed that even French and Franco-Canadians today may not agree in their experience and evaluation of the same odor³: For the French, for example, wintergreen was rated much less pleasantly than for French-Canadians.



JUST DANCE / SHUTTERSTOCK

"In France, wintergreen is used more in medicinal products than in Canada, where it is found more in candy," a press release for the study stated. "Anise was rated similarly in two cultures but was described more often as 'licorice' in Quebec and as 'anise' in France." Intricate cross-cultural differences make for intriguing anecdotes. But they are hard to document.

That's part of the reason why history is built on preserving enduring visual and tactile artifacts, such as paintings, writings, architectural sites, or simply stones and bones. What's missing is the material sensation of immediate reality that only direct sensory contact seems to provide. It is no coincidence that signs reading, "Please, don't touch the artifacts (no, seriously, don't do it)," are plastered around museums. Yet we deprive ourselves of connecting with humanity's past by focusing on materials stripped of their sensory dimensions.

ODEUROPA OPENS UP a new sensory experience of history. The researchers will create a catalog of past scents by digging through 250,000 images and thousands of texts (in seven languages), ranging from medical descriptions of smells in textbooks to labels of fragrances in novels or magazines. Machine learning will help to cross-analyze the plethora of descriptions, contexts, and occurrence of odor names (such as tobacco, lavender, and probably horse manure). This catalog serves as the conceptual basis for perfumers and chemists to create fragrant molecules fitting 120 of these descriptors.

Such recreation poses an experimental challenge that is worth following over the next couple of years. Previous experimental recreations of past scents involved the synthesis of similar compounds (if you have their chemical structure and qualitative descriptors—for example of preserved rare samples). Or it might involve blending currently available compounds into mixtures that resemble a specific description of a historical smell.

How to design a museum of scents? Part of the answer already exists. Mandy Aftel, a natural perfumer and author of the 2014 book *Fragrant*, curates in Berkeley, California, a library of curious scents. *The New York Times* said the place "manages to contain the olfactory history of the world: hundreds of natural essences, raw

Smell can enhance the feeling of visiting the past.

ingredients and antique tinctures gathered from every corner of the globe, and all available for visitors to smell." Odeuropa identifies an omission that it aims to rectify: the increasing absence of *material* presence that smells seem to convey. Smells may seem intangible and immaterial to many people. But what is the last thing that people give away of their beloved departed? Their clothes, carrying the last intimate trace of a person's being: their scent.

Part of the Odeuropa team is a research project called Smell of Heritage, carried out by Cecilia Bembibre, a doctoral student in heritage science at University College London. Heritage scientists look to come up with new ways to study materials and collections that make up cultural heritage, as well as how the environment interacts with it. Bembibre, for example, analyzes and archives culturally essential aromas. "In the heritage context," the Smell of Heritage website states, "experiencing what the world smelled like in the past enriches our knowledge of it, and, because of the unique relation between odors and memories, allows us to engage with our history in a more emotional way."

Preservationists ignored this for a long time. "A tradition of denigration of the sense of smell can be traced back to the Enlightenment," the preservationist-artist Jorge Otero-Pailos wrote in a 2016 paper, "and there is still surprisingly little serious research on a topic that, on the face of things, might be central to the discipline."⁴

Anyone living abroad traveling back home can tell you that each culture, every area, all localities have their unique smellscape: the particular foods and spices (street vendors, bakeries, family recipes), and the various kinds of industrial fumes or plant emanations. I really know I am back in Germany, not when the plane has landed (or I hear the announcement in its unmistakably staccato melody), but when I pass the scent of dusty cold cigarette smoke at Frankfurt airport's train station.

Otero-Pailos' preservationist art captures and illuminates this sort of experience. On his website, Otero-Pailos writes, "I gravitate towards monuments, the objects that entire cultures latch onto in order to transition into new phases, to remember, to celebrate, to come together." By preserving smells in architectural sites, his work creates a platform to investigate the environmental and cultural history of buildings as active and abandoned social sites.

Such research helps uncover and evaluate the impact of the world's changing materiality on society. Fish or meat markets and olfactorily rich gardens have vanished (when have you last experienced a rose that actually carries a *deep* rose smell?). They made way for shops selling electronics and bubble tea. Smells present sensory witnesses of the materials in our environment. Policies often originate in these environmental signals instead of abstract societal models. You may have escaped some stinks of the past, but you are benefitting from their consequences. For example, according to the historian Melanie Kiechle, fears of industrial fumes and stench in late 19th-century America prompted countermeasures.⁵ One was creating a green lung at the heart of a densely populated metropolis—marking Central Park's birth in Manhattan.

The historian and author of *Smell in the Eighteenth Century* William Tullett, also part of the Odeuropa project, highlights the importance of thinking about authenticity in both its sensory and historical expression. With historic spaces, smell can help lend a sense of authenticity to the experience of being there. It enhances the feeling of visiting the past, and thereby a more enduring appreciation for it. Can we experience these smells just as our historical predecessors did? That might be a stretch. A Parisian in the 18th century won't share the same judgment of the fumes of rotten fish with the same foreign fascination as our weary time traveler. That is the inherent cognitive challenge of smell—a challenge that now presents an opportunity for sensory exploration.



SCENTS AND SENSIBILITIES Using state-of-the-art techniques in history research, a new project called Odeuropa aims to conserve the smells of Europe's past.

Developing a better sense of the past and its loss may help us preserve and enrich the sensory present.

THERE IS A WONDROUS IRONY that smell, *the* sense associated with memory (and Proust's overexposed madeleine), has been sidelined in our recollections of history. Our autobiographical memories are filled with vivid smell episodes—the dust-rubber cloud in my father's garage, the bittersweet whiff of that cheap perfume of your teenage crush ... The sense of smell also poses interesting neuroscientific puzzles here. It is the only sense that bypasses the thalamus and has almost immediate access to the core cortex—including the hypothalamus, involved in the processing of new memories and associative learning. How the brain makes sense of scents has only recently garnered proper attention. How the brain makes memories with scent now makes for the next neural frontier.⁶

Developing a better sense of the past and its loss may help us preserve and enrich the sensory present. Modern life, in the 21st century, has a different sense of materiality than in the past—including the past of

the previous centuries (like the foul and fragrant richness of 18th-century France⁷). Even the lost scents of the past few decades (that alienating static smell sitting in the corridors of the bureaus of socialist East Berlin). Cityscapes became increasingly homogeneous in their sensory appeal. Today, we find the increased presence of the same shops, products, and foods almost everywhere. This homogenization has also affected our habits as travelers and somewhat dulled our sense of curiosity.

Our qualitative associations with food and drink have also changed. Some of these developments resulted from food shortages during and after the two World Wars. The impact of the industrial flavor and cosmetic industries in our daily life, with its ongoing de-scenting and re-scenting of commercial products, created a unique sensory environment for modern humans. (Many children don't know the flavor of freshly pressed orange juice and have come to associate orange with its extracted counterfeit. The same holds for vanilla and other products.)

These developments were not malicious in origin, as people skeptical of the chemical sciences may think. The work of the historian Nadia Berenstein captures the industrialization of our food products during the 20th century. It often originated in economic necessity: Producers of ersatz coffee, from malt barley, for example, tasked researchers like Tadeus Reichstein, a Swiss chemist and Nobel laureate who identified nearly 30 coffee aroma components with his colleague Hermann Staudinger, with making malt coffee smell like real coffee.

Our biosphere is in flux, too, and with it the richness of our sensory heritage. Consider the challenge of climate change with a diminishing species diversity (flow-ers and many other organic life forms). Smells, once lost, are impossible to recover—unless we try to preserve them. Perhaps the last expedition with a 19th-century Alexander von Humboldt flair is Givaudan's "Scent Trek." One of the two largest commercial fragrance producers, Givaudan, sends out researchers to capture the scent "headspace" of rare or less widespread flowers—like the plants Biangai dancers in Papua New Guinea use for decoration—as inspiration for new fragrances. (Such is the value of new scents to the multi-billion-dollar enterprise of commercial fragrance production today!)

We should not forget about our desire to sensually experience.

The historical conservation of smell visualizes (for lack of a better term) our need to directly experience and engage with the changes in our history's materiality. In a world accelerating the digitization of knowledge and the virtual documentation of other people's lives, we should not forget about our desire to sensually experience. It's vital, for me at least. Things like virtual reality, which can persuasively simulate visual, auditory, and even tactile sensations, won't feel convincing enough without also incorporating smell, the next and perhaps ultimate frontier, given how difficult it is to substitute. A fan of the outdoors like me wants to get a whiff of the horse poop. ☺

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The Joys of Being a Stoic

Science and ancient Greeks agree—Stoicism increases well-being

BY MASSIMO PIGLIUCCI

IN SEPTEMBER, A WRITER for HBO's *Watchmen* series, Cord Jefferson, was awarded an Emmy. I enjoyed the show's first season, a sequel to arguably the best movie (and graphic novel) about superhero vigilantism. The plot involves the protagonists combatting racist violence in present-day Tulsa, Oklahoma. As Jefferson, who is Black, was accepting the Emmy, he gave thanks to friends and family and, to the surprise of many, his therapist. "Therapy should be free in this country," he said. Not long after, in an interview with *The New York Times*, Jefferson expanded on his views about the importance of emotional health.¹

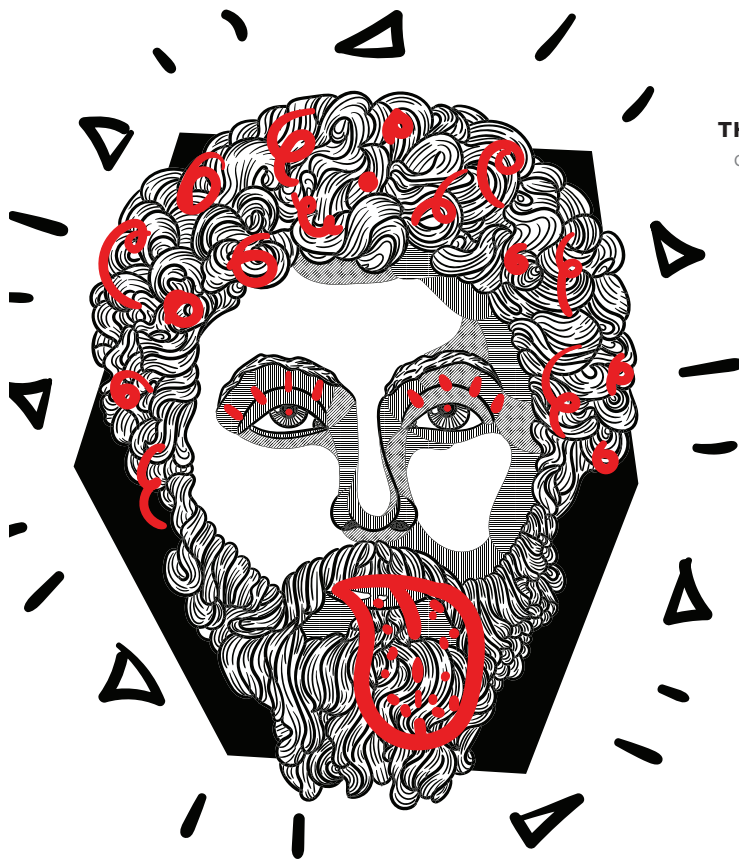
"I think Black men are taught that stoicism is important and that in order to get along in America," Jefferson said, "it's important to be stoic and keep a stiff upper lip." He noted how significant it's been for him to discard that understanding, and to see "that stoicism isn't a virtue," because it's a good thing to be sensitive to your own emotions. "That it resonated with so many people," he said, "I think speaks to the stigma people have about therapy and mental health care and admitting you are imperfect in those ways."

This statement is unfortunate. Jefferson is unwittingly perpetuating an inaccurate stereotype about Stoicism that prevents people from understanding a philosophy of life that has great potential to benefit them personally—and humanity more broadly. As you might guess, it comes from the same place as most stereotypes: a grain of truth that people misinterpret and play out of proportion. All the major Hellenistic philosophies have this problem. The word "skeptical" today often means someone who doesn't believe anything. But (most of) the Skeptics in ancient Greece said to hold your opinions lightly, because human knowledge is a tricky thing. The modern English term "cynic" means someone who has an overly negative view of life and people. But the ancient Cynics were jolly fellows who decided to live simple lives, own no property, and not marry or have children. "Cynic," in Greek, means dog-like, because the Cynics lived in the streets. In current usage, "epicurean"

refers to someone who is into highly sophisticated pleasures, but the ancient Epicureans thought that the highest pleasure is the absence of mental and emotional pain.

So it goes for Stoicism: The stiff-upper-lip stereotype finds its root in the fact that Stoics practice endurance. It arose in ancient Greece and Rome, established around 300 B.C. by Zeno of Citium in Athens. People spanning the social gamut practiced it, from slaves such as the early second-century Epictetus to emperors like Marcus Aurelius. They took to heart the idea that if there is nothing you can do about a particular situation, why beat yourself up about it? Work toward as serene a degree of acceptance as you can muster instead. This doesn't mean suppressing emotions. Rather, it means shifting your emotional spectrum—away from unhealthy emotions like anger and toward the mindful embracing of healthy ones like joy—by working on consciously altering the way you think about yourself and the world.

I don't blame Jefferson. The widespread misapprehension about Stoicism is even endorsed by a number of scholars who should know better. For instance, Edith Hall, a King's College, London, classics scholar, wrote: "Authentic ancient Stoicism was pessimistic and grim. It denounced pleasure. It required the suppression of emotions and physical appetites."² And she is not alone. There is a cottage industry of papers on stoicism in psychology, built on the same stereotype.



THE STOIC STATE OF MIND “Survey the circling stars, as though yourself were in mid-course with them,” Marcus Aurelius writes in his *Meditations*. “Visions of this kind purge away the dross of our earth-bound life.”

*If there is nothing
you can do about a
particular situation,
why beat yourself up
about it?*

According to a paper on pain management in cancer patients, for example, “Not acknowledging pain [like stoics do] in non-self-limiting conditions, such as cancer, can lead to negative outcomes and poor pain management and treatment.”³ Another paper on pain management, but in the context of home-care nurse-patient interactions, concurs: “Contemporary stoicism is often therefore seen to be ‘maladaptive’ in this context.”⁴ Other researchers are worried about “troubling stoicism,” an approach that is “characterized by silent endurance and lack of emotion—often described as a ‘stiff upper lip.’”⁵ More recently, in a preprint titled “Stoicism and Wellbeing,” Ronald Fischer, a behavioral scientist at Victoria University of Wellington, and his doctoral student Johannes Karl, describe the results of a study of 636 participants aimed at exploring the effects of stoicism on eudaimonic and hedonic well-being.⁶ Hedonic well-being refers to the experience of pleasure, while eudaimonic well-being is more concerned with meaning in one’s life.

The news ain’t good for stoicism, it seems: “We confirmed the negative effects of stoic beliefs on hedonic wellbeing observed in previous studies,” Fischer and Karl wrote. “Additionally, we found that ... stoic ideology significantly negatively predicted eudaimonic wellbeing and eudaimonic wellbeing orientation, as well as engagement in life. This indicates that a naive endorsement of stoic ideology might be detrimental to individuals’ wellbeing independent of the specific aspect.”

Well, thank Zeus I’ve never been attracted by a “naive endorsement of stoic ideology.” That’s because I practice upper-case Stoicism, not lower-case stoicism. I’m into the philosophy, in other words, not the macho attitude. Not only are the two unrelated, but in fact research from practitioners of cognitive behavioral therapy shows that the philosophy *promotes* eudaimonic well-being as well as engagement in life. The goal of Stoicism, after all, is to make us into the best human beings we can be, and it does so through the constant applications of two cardinal principles: the dichotomy of control and the four virtues.

Epictetus in the *Enchiridion* (or Manual for a good life) articulates the dichotomy of control:

Some things are within our power, while others are not. Within our power are opinion, motivation, desire, aversion, and, in a word, whatever is of our own doing; not within our power are our body, our property, reputation, office, and, in a word, whatever is not of our own doing. (*Enchiridion* 1.1)

The concept may be familiar because it pops up in a variety of other cultural traditions, from eighth-century Buddhism to 11th-century Judaism. The Serenity Prayer that begins many meetings at 12-step organizations captures the notion in modern terms:

God, grant me the serenity to accept the things I cannot change,
courage to change the things I can,
and wisdom to know the difference.

In essence, the idea is to internalize our goals: Instead of focusing, as it comes natural, on outcomes, let's pay attention to our intentions and efforts. The Stoics think that the only truly good thing for us is our own character, and that therefore the only truly bad things are whatever may undermine our character. Everything else (including health, wealth, reputation, etc.) has value, but does not define who we are.

Suppose I have a job interview coming up. I want the job, of course. But that's not up to me. It depends on the interviewer, their priorities and mood, as well as on my competition. What I can devote my attention to, however, is putting forth an appealing resume, preparing an argument for why I am a good candidate, dressing appropriately, and skipping any late-night drinking with friends the night before.

Of course, efforts and outcomes are correlated, but a Stoic's self-esteem lies entirely with her efforts. We ready ourselves mentally to accept whatever outcome with equanimity. The four virtues—practical wisdom, courage, justice, and temperance—help us in this aim. They form a sort of moral compass, ethically navigating us through whatever the world throws at us. Let's say I witness my boss harassing a coworker. Should I

Both empathy and zest for life are positively connected with Stoicism.

intervene? Practical wisdom, the knowledge of what is truly good or bad for me, tells me that I should intervene, because not doing so would undermine my character (it would be cowardly). This requires courage, because my boss might retaliate. It is also the just thing to do, if justice is understood—as it is in Stoicism—as treating other people, like my coworker, fairly and with respect. Temperance, the notion that we should do things in the right measure, neither too much nor too little, means that I can't just mumble something inaudible under my breath (too little), but also that I shouldn't punch my boss on the nose (too much).

Apply the dichotomy of control and the four virtues to everything you do and, as Epictetus promises, you will never be unhappy. You will be free, and you will live a life truly worth living. We all fall short of this ideal, of course. Yet trying to live up to it really works. My friend Tim LeBon, a London-based cognitive behavioral therapist and author, has done research on this to fight back against the “stiff upper lip” understanding of Stoicism. He's also a member of the Modern Stoicism group (to which I belong as well). These are the people who for several years have organized the annual Stoicon conference, the opportunity to live like a Stoic for a week, and a more in-depth engagement called Stoic Mindfulness and Resilience Training. Thousands of people participate every year in these activities, and Tim and his collaborators collect data on the effect of Stoicism (the philosophy) on various aspects of well-being.

It turns out that practicing Stoics experience a statistically significant increase in measures of their well-being, with fewer episodes of negative emotions (like anger) and more episodes of positive emotions (like

I'm into Stoicism the philosophy, not the macho attitude.

joy). Moreover, such reduction of anger does not take place by way of suppression (which is impossible), but because Stoic practitioners reframe what happens to them in terms that simply do not trigger angry reactions in them. “We stop having ethically misguided and intense or conflicted emotions (sometimes called ‘passions’) and we move toward having ‘good emotions,’” as the handbook for the 2020 edition of Stoic Week states. “The passions are misguided because the passionate person supposes that happiness depends on acquiring or retaining ‘preferred indifferents,’ such as wealth or fame (rather than on exercising the virtues).” This folly leads to anger, fear, or overwhelming lust, emotions often marked “by intensity of feeling, instability and inner conflict.”

In other words, everyday sorts of anger, fear, and the like affect Stoics less because we have realigned our priorities in life toward what we think really matters: being a good person and relating positively to other human beings. Wealth, reputation, and even health we take if they come, but we can do without if they go. Of course, no matter your philosophy, no one is emotionally immune to truly life-altering events. Even so, Stoicism can help us manage something that is terrifying, tumultuous, or deeply sad.

For instance, when my mother died a few years ago, I was mentally and emotionally ready because of my ongoing Stoic practice. This didn't mean that I wasn't

upset when I found out her terminal diagnosis, or that I didn't grieve for her afterward. But it did mean that I was present, completely alert to what was going on, focused on spending as much time as possible with her before she went. I was also able to handle my grief and be helpful to my family during the painful but necessary arrangements that had to be made before and after her departure.

Predictably, Stoicism is linked to the four cardinal virtues, but the data also shows that other measures of character strength—including gratitude, kindness, hope, and love—are all positively associated with Stoic practice. Finally, both empathy and zest for life are positively connected with Stoicism, with zest actually increasing after just one week of practice.⁷

This all amounts to a circumstantial case that Stoicism is very different from stoicism. Do we have any direct empirical evidence? Yes, we do, again thanks to Tim's systematic efforts.⁸

This year's Stoic Mindfulness and Resilience Training saw about 5,000 people enrolled. They were given two questionnaires to measure their Stoicism (the Stoic Attitudes and Behaviors Scale) as well as their stoicism (the Liverpool stoicism scale, the one used in most psychological research). The results showed a slightly negative, but in fact statistically null, correlation between Stoicism and stoicism, contrary to what the psychologists and classics scholars I mentioned above state or

imply. If you practice Stoicism, you are just not inclined toward sporting a stiff upper lip.

Moreover, after a month of training as a Stoic, one's degree of philosophical Stoicism predictably increased, while the same people's degree of "stoicism" decreased. Practicing the philosophy actually makes it less likely that people adopt the stiff-upper-lip attitude.

You might ask why anyone should embrace a philosophy of life that is more than two millennia old. Hasn't human understanding advanced since? I could point out that other traditions—Buddhism, Confucianism, Christianity—are also thousands of years old, and yet plenty of people find them invaluable.

But more importantly, all philosophies of life (including religions) inevitably and sometimes consciously change over time, and adapt to new socio-cultural environments. The ancient Stoic philosopher Seneca wrote:

Will I not walk in the footsteps of my predecessors? I will indeed use the ancient road—but if I find another route that is more direct and has fewer ups and downs, I will stake out that one. Those who advanced these doctrines before us are not our masters but our guides. The truth lies open to all; it has not yet been taken over. Much is left also for those yet to come. (Letters to Lucilius, 33.11)

Accordingly, modern Stoics are updating both their exercises⁹ and their general philosophy on the basis of the best that modern science and philosophical discourse have to offer. Stoicism's answer to the question of how to live a good life began 24 centuries ago, but it is still very much evolving today. You may want to give it a try. No stiff upper lip required. ☺

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How to Fix the Wildlife Conservation Crisis

The ongoing COVID-19 pandemic has exposed long-standing weaknesses in how we protect African wilderness and species

BY RACHEL NUWER
PHOTOGRAPHS BY PETER CHADWICK



KAFUE NATIONAL PARK in the heart of Zambia is one of the largest protected areas in Africa, encompassing a wilderness the size of New Jersey. Rivers meander through woodlands, teak forests, and open plains that are home to at least 500 bird species and 158 mammals, including lions, cheetahs, ground pangolins, leopards, and endangered African wild dogs.

Though it has a bounty of biodiversity, like many protected areas in Africa, Kafue is far from realizing its full potential. The park is large enough to support three to four times the number of animals currently present, but poaching, habitat fragmentation, and the loss of connectivity to other nearby ecosystems have long acted to suppress wildlife populations.

Yet by late last year, things were improving. Tourism had lessened people's need to poach wildlife for money or food and encouraged them to see animals as an asset rather than a threat. Grants from the United States and Europe have provided funding to protect three increasingly large core zones in Kafue from poachers. "After 18 months of intense patrolling, we felt like we were just turning a corner in terms of getting on top of poaching and wildlife beginning to recover," says Kim Young-Overton, director of Panthera's Kavango-Zambezi Transfrontier Conservation Area, which includes Kafue.

Then came the pandemic. Virtually overnight, it was "like a tap [was] turned off," Young-Overton says. The tourists disappeared, taking with them the dollars that the park and surrounding communities depend on. The absence of foreign visitors also left a dent in security. Without all those extra eyes and ears on the ground, it was "like leaving the front door open," Young-Overton says. Poachers could now enter the park without worrying about running into safari operators and their guests.

In the months since the pandemic began, bushmeat poaching in Kafue's formerly secured core zones has returned to the same level as two years ago, before the security overhaul. From May to August 2019, for example, rangers recovered just 25 snares from boundary areas surrounding the core protection zones,

whereas this year, they found 136 snares over the same period. The amount of bushmeat seized over the same period has also skyrocketed, from about 100 pounds last year to more than 3,300 pounds this year. Two lions—both breeding females—have been killed in the core protection zones, something that "just outright never happened" prior to the pandemic, Young-Overton says.

The pandemic will almost certainly leave long-lasting impacts on Kafue's wildlife and surrounding communities, Young-Overton says. Animal populations take much longer to recover than to decline, and the cascade of local poverty brought about by COVID-19 will not resolve itself overnight.

Across Africa, where the vast majority of protected areas already operate on a shoestring budget, similar scenarios are playing out. The pandemic has laid bare what conservationists have been warning of for years: that support for Africa's nature is grossly inadequate. But rather than just highlighting and exacerbating this fact, many experts believe that COVID-19 presents a unique opportunity to completely revamp the way the world approaches conservation in Africa, which is currently almost entirely reliant on the fickle tides of tourism and the whims of donors. Through the fog of struggle and loss, conservationists see a chance to rebuild the status quo into something that is significantly more self-sustaining, resilient, and equitable.

EXTREME MEASURES A white rhino stands before a setting sun in the Phinda Private Game Reserve shortly after its capture by wildlife biologists. Like many others, this rhino was later dehorned as a means of protecting it from poachers.



Doing so, however, would require a major overhaul in how the world values and contributes to conservation in Africa. While this is no small task, groundbreaking projects scattered around the continent are showing that we already have the tools needed to both diversify and amplify Africa's conservation funding stream. Now, we just need to find the collective, global will to scale up those efforts.

"IF IT PAYS, IT STAYS" is a phrase commonly heard in Southern African countries with regard to justifying wildlife's presence on the landscape. But this sentiment could just as well be applied across the continent. Conservation for conservation's sake is not a luxury that Africa's growing, oftentimes impoverished populations can afford. Unlike in the U.S. or Europe, taxpayers in

Africa generally do not subsidize the continent's 7,800 terrestrial protected areas. In some cases, African parks and reserves even pay the government a portion of their revenue, the bulk of which come from tourism and, to a lesser extent, donations and aid.

For the majority of protected areas, the sums brought in from tourism and other sources are far from adequate. According to a 2018 paper in *Proceedings of the National Academy of Sciences*, many such reserves are "paper parks," or areas designated for conservation solely in name.¹ They lack the resources to actually implement conservation on the ground. The paper's authors calculated that 90 percent of the nearly 300 protected savannah ecosystems in Africa they analyzed face crippling funding deficits—to the collective tune of at least \$1 billion.



LOSING LIONS Lion populations in Africa have declined by 43 percent over the past two decades.

If those shortfalls are not addressed, iconic species like lions—which the authors estimated have already decreased by 43 percent over the last two decades, to fewer than 20,000 individuals remaining in the wild—will disappear. And eventually, many cash-strapped protected areas will be lost to development, too. “Budget deficits come at a time when Africa’s human population is growing, and the continent is developing quickly,” says Peter Lindsey, director of the lion recovery fund at the Wildlife Conservation Network, and lead author of the findings. “This poses a risk that underfunded protected areas will become swamped by human pressures.”

Although wildlife-based tourism is not profitable enough to prop up an entire continent’s conservation, its contribution in Africa is still significant, generating more than \$29 billion annually and employing 3.6 million people. It is difficult to overstate just how devastating a blow the pandemic has dealt to tourism. “COVID-19 has really exposed what I’d call the soft underbelly of

African conservation’s reliance on tourism,” says Tim Tear, the tropical program director at the Biodiversity Research Institute. While ebola, terrorist attacks, and political unrest have driven visitors away from various countries and regions in the past, “nothing has ever hit all at once before,” Tear says. “That’s a shock I don’t think anyone saw coming.”

In a *Nature Ecology and Evolution* paper published in July, researchers report that 90 percent of African tour operators have experienced a 75 percent or greater decline in bookings.² For some, it has dropped by 100 percent. In Mozambique, for example, more than half of the country’s protected land is allocated for management and use by trophy hunting companies, all of which have lost most or all of their bookings to the pandemic. “Zero foreign clients is where we’re sitting at the moment,” says Holly Rosier, the head biologist at Coutada 9, a 1,660-square-mile conservation area that relies on hunting proceeds for virtually 100 percent of its budget. “It’s a complete nightmare.”



WHO'S THE BOSS? African elephant bulls display displacement behavior during fighting to determine dominance, seen here in Addo Elephant National Park, Eastern Cape, South Africa.

Like most other hunting concessions in Mozambique, poaching and civil war had virtually emptied Coutada 9 of wildlife prior to the arrival of Rosier's employers. Fifteen years after taking over the lease, anti-poaching activities and efforts to build relationships with local communities were finally starting to pay off. Coutada 9 is home to elephants, lions, and leopards, as well as rare herbivores such as the Lichtenstein's hartebeest. But with no money coming in, management has been forced to lay off a third of Coutada's scouts. Poaching—including of three lions (one of which they managed to save)—appears to be on the rise. And Rosier worries that wildlife losses will only become worse if communities, which normally receive 25 percent of hunting profits, are not paid at the end of the year. "It's going to be really important to make clear why they're not getting that money, because any form of resentment will come back tenfold," she says.

National parks and other government-run protected areas have also been hit hard. Most government

Animal populations take much longer to recover than to decline.

agencies from East and Southern Africa that have a strong wildlife tourism sector are reporting a 70-to 90-percent decline in conservation revenue, says Kathleen Fitzgerald, a partner at Conservation Capital, a company that develops business-driven solutions to support conservation. "It's very fair to say a majority of the protected area funding is at risk."

Involving local communities is key to long-term success.

As budgets have been slashed, livelihoods upended, and poverty increasing, many protected areas like Kafue are reporting an uptick in bushmeat poaching. In Mozambique's Limpopo National Park, for example, rangers are accustomed to battling sophisticated poaching gangs that target rhinos. But since COVID-19 hit, they have started intercepting "groups with rifles coming in with donkeys, to shoot antelope, buffalo, and kudu and take the meat back," says João Almeida, a wildlife veterinary officer at Saving the Survivors in Mozambique. "This is something they've never had before on that scale."

In April, the International Union for Conservation of Nature (IUCN) sent out a survey to wildlife managers across Africa and received responses from 19 countries. Half said that the pandemic had crippled their ability to conduct anti-poaching activities. All reported at least some impact to their conservation operations, including a compromised ability to pay staff salaries, to monitor illegal wildlife trade, and to reduce human-wildlife conflict in local communities. Seventy-nine percent of the directors believed that, without help, they would not be able to maintain basic operations under COVID-19 for more than six months. While Kenya and some other countries have stepped up with emergency subsidies to support rangers and other short-term conservation needs, in most places, conservation ranks far down the priority list in terms of pandemic relief. This is nothing out of the norm in Africa, where protected areas, even during ordinary times "have always been neglected when allocating national budgets," says John Waithaka, the East and Southern Africa regional vice chair of the IUCN's World Commission on Protected Areas.

Zimbabwe's conservation division, for example, doesn't "get a single penny from the treasury," says

Patience Gandiwa, an executive technical advisor on international conservation affairs for the government's Parks and Wildlife Management Authority. The parks authority has gotten around this by raising money through tourism, donations, land leases, and grants, to the point that, in December 2019, the agency finished paying off a \$25 million legacy debt. Finally out from beneath that burden, Gandiwa and her colleagues were looking forward this year to hiring hundreds of new rangers, investing in amenities for the agency's 3,200 existing staff, and renovating tourist camps across the country. "2020 was promising to be such a big year," Gandiwa says. "Then COVID visited us." The parks authority has enough money in the bank to pay staff salaries, at max, through the first quarter of 2021—and not at a level commensurate with Zimbabwe's high inflation rates. "You get enough to survive," Gandiwa says. "We're just hoping with the slow opening up of tourism we'll start to have a little bit more income so we don't completely run dry."

It remains to be seen to what extent African governments and other nations, and the international community, will step up in the longer term to support struggling protected areas devastated by the pandemic. "We have seen an influx of donor support to help fill the short-term gap, which is great, but it's just absolutely not enough, full stop," Fitzgerald says. The extent of long-term aid will also likely be affected by the economic tides of the coming months and years. The last global financial crisis caused total charitable giving in the U.S. to drop by 7 percent in 2008 and 6 percent in 2009.

Without help, protected area operations will continue to be scaled back or cease functioning altogether, Lindsey warns. Poaching will accelerate, as will other illegal activities like mining, logging, and livestock grazing. "In many parts of the continent, if you take your foot off protections of natural assets, they will be exploited," Lindsey says. "There's a great risk of acute impacts on conservation."

BAILOUTS AND EMERGENCY ASSISTANCE may be necessary in the short term, but they're not sufficient to bolster protections in the long run. What's really needed, many conservationists believe, is a complete reboot to the way the world approaches wildlife

protection in Africa. Pulling off this massive undertaking would only be possible through buy-in from local and international policy makers, philanthropists and business leaders, as well as the global community at large. It would also require, in various places, addressing major challenges ranging from poverty, education, corruption, and mismanagement to incompatible legislation and colonial approaches to conservation. Success would by no means be guaranteed. But not trying, Lindsey says, will result in “an ongoing attrition of Africa’s natural resources and huge decreases in biodiversity—there’s no doubt in my mind.”

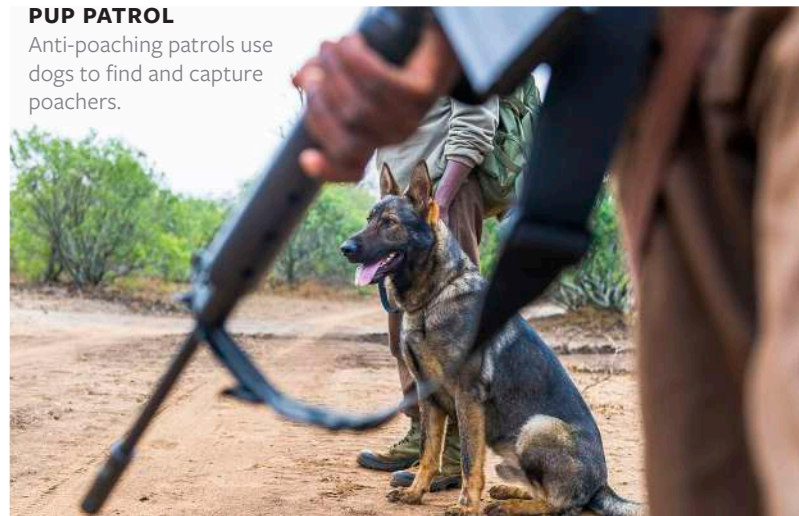
The good news is that a number of African leaders are already well aware of the need for such a paradigm shift. In April, Benjamin Mkapa, the late former president of Tanzania, spoke by video conference to dozens of heads of Africa’s protected areas. National parks, he emphasized, are key to creating “the healthy, prosperous, and sustainable Africa that Africans so desire,” and conservation should be made the centerpiece of new sustainable and resilient economies.

There will not be a one-size-fits-all solution for realizing such lofty goals. Instead, a suite of diversified approaches will be needed, ones that are tailored to different countries’ legislative, social, and ecological features. Not relying on a single source for funding conservation will also guard against the possibility of future shocks, including another pandemic-level disaster. “If you diversify income, you have less dependency and therefore less vulnerability,” says Josep Oriol, a managing partner at Okavango Capital Partners, a company that develops and invests in market-based conservation solutions.



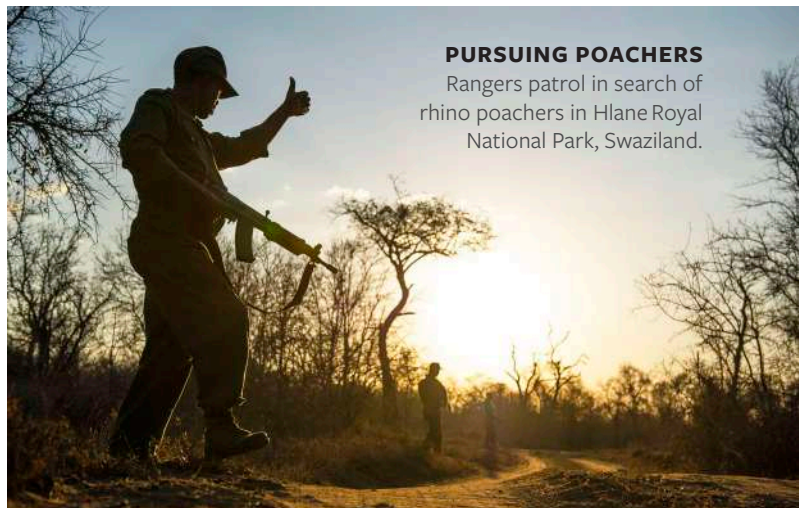
DRASTIC MEASURES

Biologists prepare to dehorn a white rhino, a practice aimed at preventing poaching.



PUP PATROL

Anti-poaching patrols use dogs to find and capture poachers.



PURSUING POACHERS

Rangers patrol in search of rhino poachers in Hlane Royal National Park, Swaziland.

MUD BATH A Cape buffalo bull emerges from the cooling water of Lake Nakuru.



In the near term, public-private partnerships are one tool that African governments can turn to to help build their conservation capacity. For example, African Parks, a South Africa-based nonprofit group, has taken over managerial duties for 16 formerly struggling national parks in 11 countries, including in tourist-scarce places such as Benin, Chad, and DRC. Funding from philanthropists, nonprofit groups, and the E.U. and U.S. allows African Parks to bridge the budgetary gap while it rehabilitates the environment, wins over local communities, and builds up tourist infrastructure. “Ideally, we need 10 or 20 African Parks,” Lindsey says. “[This organization is] extremely effective at managing protected areas.”

For some countries, though, a shift in legislation and political culture would be needed to hand over the conservation reins to a nonprofit group or other outside entity. In Cameroon, for example, land and wildlife belong solely to the government—a top-down approach that “is not always that good,” says Roger Fotso, director of the Wildlife Conservation Society’s Cameroon program. Corruption, mismanagement, and a lack of resources have prevented the country from realizing its full potential for conservation and have also excluded Cameroonians from a sense of environmental ownership. “People do not see the direct benefit,” Fotso says.



THREE'S A CROWD Burchell's zebra stallions make their way across the savanna in Addo Elephant National Park, Eastern Cape, South Africa.

Encouragingly, though, when the government has tried a different approach, the results have been positive. In 2012, for example, the Wildlife Conservation Society worked with the Cameroon government and rural communities to create Deng Deng National Park, a forested landscape home to gorillas and chimpanzees. The original plan was to secure 60 square miles, but there was such an outpouring of community support that the area was expanded to 260 square miles. The



HELLO THERE! A Cape vulture peers into a remotely operated camera.

black rhinos, and at least 150 desert lions—formerly estimated to number fewer than 25—now roam the country’s northwest.

But Namibia’s conservancies are still vulnerable: They derive approximately 90 percent of their income from photographic and hunting tourism. This emphasizes the importance of developing other, more sustainable, diversified, and resilient ways to earn revenue from nature. Fortunately, projects scattered around the continent are showing this is possible. The key

communities living nearby “were part of the discussion, they did not just sit back and see something coming,” Fotso says. “There’s many examples like that, showing that people will be willing and supportive if they feel like they’re a part of the process.”

Indeed, whether protected areas are managed by governments, nonprofit groups, individuals, or companies, involving local communities is key to long-term success. This is necessary from both an ethical and practical standpoint. Living near a protected area can come with steep costs in terms of land that is not available for use and danger posed by animals that can kill people and livestock, and consume or trample a year’s worth of crops overnight. If an impoverished rural community does not reap any benefit from a nearby protected area, they will often come to resent it. They may target it for illegal activities—or look the other way if they see a neighbor doing so.

On the other hand, if a protected area does bring benefits through jobs, development, and opportunities, both people and wildlife can flourish. Namibia—where 86 communal conservancies manage 66,000 square miles of wilderness—best exemplifies this on a large scale. Since the first conservancies started operating in 1998, Namibia’s elephant population has more than tripled. It has become a stronghold for critically endangered

will be to replicate and grow them, while also exploring more innovative ideas that conservationists and policy makers are only just beginning to consider.

Many alternative funding approaches hinge on the idea that Africa should be compensated for the vital global ecosystem services that it has, until now, provided to the world virtually free-of-charge. The Congo Basin, for example, is home to the second-largest tropical forest on the planet, providing indispensable carbon mitigation services.

Developed countries, many of which are largely deforested, can help to more fairly shoulder this burden through a variety of means. For example, relief from government debt in exchange for protection for nature is one win-win method that is currently being trialed in the Seychelles by NatureVest, the conservation-investing unit of the Nature Conservancy. Developed countries can also simply pay African countries directly for biodiversity, carbon storage, and other ecosystem services. In 2019, for example, Norway agreed to pay Gabon \$150 million to preserve its rainforest. “If we have ecosystems that host a number of endangered species, surely, can’t we put a value to that?” says Gandiwa at Zimbabwe’s park’s authority. “I can imagine a time when we start to see our biological assets appearing in our bank accounts.”



PLAYING FOR KEEPS

A black-backed jackal lunges at a sandgrouse that has come to a watering hole to drink along the Nosob Riverbed, Kgalagadi Transfrontier Park, Northern Cape, South Africa.

Around a dozen biodiversity and carbon offset projects are already scattered around the continent. In Zambia, for example, BioCarbon Partners, an Africa-based company created to manage long-term carbon projects, is using carbon offsets to conserve a formerly unprotected wilderness of nearly 4,000 square miles, an area larger than Yellowstone National Park. “Zambia is the fourth most forested country in Africa, but it has one of the highest deforestation rates on the planet, all poverty-driven,” says Oriol, who is also a founding board member and investor of BioCarbon Partners. “It was super important to act quickly.”

The Zambia project has been a resounding success for both conservation and local communities. Last year, a major European energy company purchased nearly all of the 1.5 million tons of available carbon credits, and the 222,000 people living in the area have so far received an equivalent of around \$2.2 million for keeping the ecosystem intact. Without this revenue source, families in the area would typically earn an average of just \$20 per month, so for many, Oriol says, the money has been life changing. Oriol and his colleagues aim to double the Zambia project’s size over the next three years.

Bringing together the conservation and development communities would also be a boon in terms of funding, capacity building, and potential positive outcomes. Human-oriented development organizations operate in their own silo and receive orders of magnitude more funding than conservation groups do. According to an Organization for Economic Cooperation and Development report, in 2017 alone, the global community donated \$52.8 billion to Africa in development aid. No figure readily exists for total



AL FRESCO Spotted hyenas scavenge a kudu carcass in Addo Elephant National Park, Eastern Cape, South Africa.

annual conservation donations to Africa, but according to Lindsey, the amount is certainly in the mere millions. Development and conservation are intimately connected, however; human well-being depends on healthy ecosystems, and maintaining those ecosystems depends on developing sustainable green economies. “We as conservationists need to make that case clearer and more strongly,” Lindsey says.

Similar funding silos exist, Tear adds, for everything from mercury pollution and desertification to wildlife trade and climate change. These problems overlap in their impacts on people and the planet, and they also share a common driver—overexploitation of the natural world. But the lack of coordination among the people and groups trying to solve these issues detracts from everyone’s overall effectiveness. “Essentially, they’re all pulling in the same direction, but not pulling together,” Tear says. The question, he adds, is whether we can corral these various efforts to work toward a common goal of sustainability.



WORKING TOGETHER A young Mozambican child waves from outside his home. Conservation efforts work best when local communities are involved.

All of these changes will of course require political will, which is something that has been sorely lacking when it comes to conservation at large. According to a United Nations report published in September, the global community has failed to meet commitments set a decade ago to protect biodiversity. One way society at large can help to reverse this trend is by electing leaders who care about the planet and holding them accountable to environmental commitments, says Amy Dickman, a conservation biologist at the University of Oxford. “If you’re living in a democracy, then use that democracy to have a voice for nature,” she says. “We have to show that we want governments that are going to take this seriously, that we want proper investments in our world and our future.”

Such changes are necessary not just for Africa’s protected areas and people, but for all of us. The economy, experts agree, is not a valid argument against investing in the future of our planet. In the short term, Tear points out, there are “massive funds” available globally that could be better coordinated to cover the costs of changing our ways, and those investments would very quickly pay off. According to a report published in September by the Paulson Institute and the Nature Conservancy, the world would have to spend \$598 to \$824 billion annually over the next 10 years to stop the impending extinction crisis, reduce the risk of future pandemics, and maintain ecosystem integrity in Africa

Human well-being depends on healthy ecosystems.

and beyond. It might sound like a lot, but compare that to the at least \$2.6 trillion that the COVID-19 pandemic has so far cost humanity—a figure that may wind up ballooning to up to 10 times more, according to a recent *Science* opinion piece.³

Because humans respond better to urgent crises than gradually increasing risks, Tear says, the pandemic could provide the momentum necessary for activating much-needed changes in how we approach nature. On the other hand, if we fail to take advantage of this opportunity and return to business as usual—fragmenting landscapes, exploiting wildlife, polluting, and neglecting nature—more pandemics will come. Species will be lost and ecosystems will collapse, taking with them life-sustaining services such as freshwater, pollination, and carbon sequestration. Human and planetary suffering will reach heights previously unimaginable. Put in those terms, investing in our future would be an absolute steal—and Africa would be the perfect place to start. ☺

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Reading, That Strange and Uniquely Human Thing

How we evolved to read is a story of one creative species

BY LYDIA WILSON



THE CHINESE ARTIST XU BING has long experimented to stunning effect with the limits of the written form. Last year I visited the Centre del Carme in Valencia, Spain, to see a retrospective of his work.

One installation, *Book from the Sky*, featured scrolls of paper looping down from the ceiling and lying along the floor of a large room, printed Chinese characters emerging into view as I moved closer to the reams of paper. But this was no ordinary Chinese text: Xu Bing had taken the form, even constituent parts, of real characters, to create around 4,000 entirely false versions. The result was a text which *looked* readable but had no meaning at all. As Xu Bing himself has noted, his made-up characters “seem to upset intellectuals,” in a sly sendup of our respect for the written word.

There was a long way to go from recording goods to writing great works of literature.

In another room was *Book from the Ground*, a slim volume, displayed in a room of Xu Bing's inspiration: symbols and emojis, gathered from around the world and from different contexts, from an airport to a keyboard. Xu Bing scoured the world to find universal images and the result stands in stark contrast to *Book from the Sky*: This book was designed to be read by anyone. The first page was slightly awkward to read, translating the pictures to the (in my case, English) word. But as I turned the pages, the meaning emerged more fluently, and I was drawn into its story of a day in the life of an office worker. It was as if Xu Bing was asking me to wonder what was happening in my brain as these tiny pictures on the page transformed into meaning, a narrative. How was the process of reading pictorial symbols different from reading letters based on phonetic symbols?

Xu Bing was illustrating what recent studies in neuroscience have revealed: People everywhere read words made from pictures, such as Chinese characters (known as pictographs), and words made from letters, in a remarkably similar way. It's an insight that opens a window on how writing developed and how we read—and how we might tap deeper wells of creativity and communication.

HUMANS IN DIFFERENT places and times have felt impelled to overcome the limitations of pictures in communicating. Despite the pressing need to capture spoken language in this form, some societies never felt the demand. Until colonialism, aboriginal communities

in Australia lived in societies governed by extremely complex laws that passed through the generations entirely through oral means. For tens of thousands of years, rules governing hunting, finding your way, marriage, and ceremony have been embedded in song and performed, learned, and taught in everyday life. There's beautiful sacred rock art throughout the continent, and symbols used for specific identification, but neither developed into a written system to capture a whole language.

Some of the earliest writing—symbols for meaning rather than pictures alone—is from Mesopotamia, dated to around 3000 B.C.; clay tablets dug up in the archaeological site of Kunara, near the Zagros mountains in modern-day Iraqi Kurdistan. These tablets record quantities of goods in a form of bookkeeping—incoming and outgoing amounts of flour and grains. “The thing about human ingenuity is that when there's a sharp need for something, it tends to crystallize in discovery,” says Irving Finkel, an assistant keeper of ancient Mesopotamian script, languages, and cultures in the British Museum. Necessity being the mother of invention, in other words. “It's very probable that it was [a] kind of administrative responsibility which produced the first stumbling attempt at writing and then eventually a proper fluent script,” Finkel says.

Egyptologist Gunther Dreyer came to similar conclusions during a lifetime of excavating Ancient Egypt, discovering artefacts crucial to our understanding of the development of writing. “Why is there a need to write something down? I think the reason for that is simple,” Dreyer says. “Those are the requirements of accounting.” Dreyer points out that ruling back then, as today, involved “collecting taxes and redistributing. And in a big area, you somehow needed to note down who delivered what when.” Indigenous Australians feeding themselves and their communities through a hunter-gatherer lifestyle, bartering goods with other communities, didn't need to record such trade, either for a third party far away (such as a tax office) or for posterity.

But there was still a long way to go from recording goods and quantities to writing great works of literature. Humans all over the world faced the same problems in expressing themselves beyond the here-and-now that speech has covered. It turns out that every



WRITE ON Writing arose at different places around the globe, diverging from pictographic to alphabetic symbols. But when we look deep inside the brain, it turns out people everywhere write and read in remarkably similar ways.

ancient writing system solved these problems in exactly the same way. “We like to call it the giant leap for mankind,” Finkel says. The leap is from using a picture as a picture (a logogram) to using it to portray a sound (or phonogram)—the Rebus Principle. Many children play a game using this principle, when they discover that a bee can be used for the sound “be,” and combined with a drawing of a leaf, these two unrelated objects can suddenly produce a meaning—belief.

But then ambiguity arises: When is a bee a bee, and when is it a sound? Cuneiform, Egyptian, and Mayan hieroglyphs and Chinese all solved the problem in the same way: They added unspoken elements now known as “classifiers” to clear up whether the writer is talking about keeping bees or simply using “be” as a sound. Chinese still uses this system, with picture, phonetic, and classifier elements all crucial to their written system. But in other places a different system took over: the alphabet, invented around 4,000 years ago in the Sinai Peninsula. Stripped of anything but sound, this handful of symbols can be learned quickly, unlike the thousands of Chinese characters that must be mastered

for literacy. After a few centuries of remaining at the margins, the alphabet from the Sinai swept through Europe and much of Asia and Africa, changing into the dizzying range we have today.

NO WRITING SYSTEM goes back much further than 5,000 years, a mere blink of an eye in evolutionary terms. “Relative to speech [reading is] very young,” says Tae Twomey of University College London, who has spent her career looking into this new trick of *Homo sapiens*. “The part of the brain that deals with reading had to evolve somehow from the brain that we used before writing was invented.” And it wasn’t just one part that was recruited. “If you think about it, it’s a complex task. You are extracting visual information in order, ultimately, to get to a meaning.” Once I do start to think about this process—a process I can’t remember not being able to do—it starts to seem extremely alien: Thoughts, ideas, instructions, information are being transferred from one human brain into mine, via my optic nerve. But the visual element is only part of the story.

It was a giant leap for mankind—using a picture to portray a sound.

Twomey's research uses scans to show the different areas of the brain that are active when we read. "It's a distributed network," she explains. Neurologist Thomas Hope, a senior research associate at University College London, offers an analogy. "Like most cognitive behavior, we think reading works like the Nile Delta." It's not fed by one stream, he says, "but a bunch of potentially redundant streams."

For reading, there are two large tributaries, broadly correlated with sound and vision. (The third major area working on the task is the Broca's area, in charge of executive function, which acts as the conductor, orchestrating all the inputs.) Beginning readers sound out each letter to get to the meaning. "Reading is not just to communicate meaning, but also to communicate generally," Hope says. "And the most common way that we communicate is by speaking. So when you read a word, some part of your brain is sounding out what that word would sound like if you were saying it or if someone was saying it to you." And that act of speech communication is the same across cultures, whatever the written form of the language, so most readers will be hearing as they read.

But sound isn't all. "I've been watching my children learn to read," Hope says. "You can't learn to read just by learning the letters. You have to learn to understand and recognize the words, too." Readers in

an alphabetic system have to learn the equivalent of characters: Learning the shape of a word is basically the same job as extracting the meaning from a pictographic character. But once we get more fluent at reading we tend to use a different tributary more. "Another way, that most skilled readers prefer, is to recognize the whole word as a single entity and connect it directly to meaning," Hope says.

The so-called "Cambridge letter," a meme in 2003, gives a proficient reader a chance to test this latter mode of reading, through shape recognition rather than sounding out the letters:

Aoccdnig to a rscheearch at Cmabrigde Uinervtisy, it deosn't mttair in waht oredr the ltteers in a wrod are, the olny iprmoetnt tihng is taht the frist and lsat ltteer be at the rghit pclae. The rset can be a toatl mses and you can sitll raed it wouthit porbelm. Tihs is bcuseae the huamn mnid deos not raed ervey lteter by istlef, but the wrod as a wlohe.

Most people can extract the meaning from this quotation without too much problem, which seems to prove its point: You can read using a general impression of the word rather than relying on the sound. But as Hope tells us, the history of research is a history of overturning simple explanations to find more

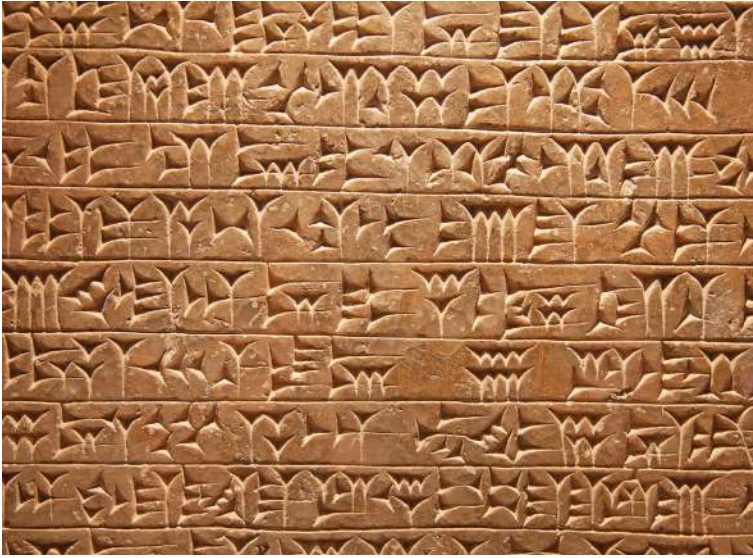
interesting, if complex, stories below. In fact, jumbling the letters of a word *does* matter, for some words more than others, and in some sentences more than others.

Matt Davis, at the University of Cambridge (where this research did not take place; the first mistake of the meme), put together a handy blog post on faulty thinking about the letter. First is the fact that two or three letter words do not change at all: the second sentence leaves “the,” “can,” “be,” “a,” “and,” “you,” “can,” and “it” unchanged, giving our brains a lot of easy information to go on. Another feature of the meme is that no word has been misspelled in such a way that it spells a different word—Davis uses the example “salt” and “slat” as a problem that’s been avoided—and further, each jumbling has put letters close to where they originally were: “Cmabrigde” might be recognizable (especially when followed by “Uinervtisy”) but is far harder when written “Cgbairrde.” Finally, the examples chosen all retain the right sounds of the original words they’re scrambling; the “th” in “without” is preserved in the way they’ve scrambled the letters. And that’s because sound, as it turns out, *does* matter.

In a recent experiment, Twomey scanned individuals’ brains as they read. Her experiment was based on her own roots of learning to read in Japan. Every Japanese child learns two systems of writing, the kanji system, based on Chinese characters, and the kana system, which is purely phonetic (though the units are syllables rather than the individual sounds of alphabet systems). This dual approach lasts their entire lives, with all books written in both systems (except for children’s books, for learning purposes). This means that you can test the difference in reading different scripts without worrying about controlling for reading proficiency or language differences. The working assumption of many scholars was that the brain scans of people reading pictographic scripts would show an emphasis on the visual part of the brain, the meaning extracted by recognizing the character, in contrast to those reading a phonetic script, who would be using the sound of the letters to arrive at meaning. What Twomey’s scans showed was that the same areas were activated when reading both types of script.

The experiment compared reading strategies within one individual who had learned to read in two systems. Twomey conducted other research that compared

Our teaching systems aren’t penetrating the creative depths of our reading brains.



BOOKKEEPING

This example of ancient cuneiform writing dates back to the Bronze Age. Irving Finkel of the British Museum says “a kind of administrative responsibility produced the first stumbling attempt at writing and then eventually a proper fluent script.”

No writing system goes back much further than 5,000 years, a blink of an eye in evolutionary terms.

reading strategies between individuals, scanning the brains of people reading in Chinese and English. The differences between readers in this experiment wasn't straightforward to understand. “At first we thought the difference we saw in the brains was due to the difference in scripts they were reading,” Twomey says. “But when we looked at dyslexic readers, they were using both areas, regardless of what script they were reading, which suggests that it has nothing to do with script itself.”

Twomey interprets this surprising finding as evidence of a difference in reading strategies that result from how we learn to read. English readers are taught with a phonics system, using rhymes and other sound-based exercises; Chinese is taught through writing, and associating the character on the page with the meaning directly. Twomey says that dyslexic readers, in their struggle to learn to read, are calling on more of the tributaries in the brain to overcome their difficulties of whichever script they are being taught. This showed up in their brain scans: The pathways used to extract meaning were the same for dyslexic readers whether they were reading pictographic Chinese or the phonetic alphabet. There were no differences between reading picture-based and sound-based words for the brain, just differences in how we've been trained to do the job.

The artist is now echoed by the scientist in showing the extraordinary success of our species.

Hope, who has read and admired Twomey's research, offers a summary. "The key point is we're all of us using both of these pathways all the time," Hope says. "You and I might differ slightly in our preferences for them, but we're still using them both." This 5,000-year-old technology of humans, which arose at different places around the globe, first used similar systems combining phonetic, pictographic, and classifier elements; a divergence came with the invention of the alphabet, which itself proliferated into such differing forms as Cyrillic, Arabic, Armenian, Tibetan, and Hindi—to name a few. But when we look deep inside the brain, it turns out that we are all doing this strange activity in similar ways.

What this says about teaching is yet to be fully explored, but Twomey's research suggests that our teaching systems aren't penetrating the depths of our reading brains. Of course we learn to extract meaning from squiggles on a page, or you wouldn't be reading this. But we could be taught to use more of the tributaries involved, as dyslexic readers seem to be doing to compensate for their difficulties. If non-dyslexic readers of phonetic scripts, which are usually taught initially through sound-based learning, were also encouraged to learn the word shapes from the start; if those learning pictographic characters chanted them out loud as well as copying them out to memorize them; who knows

what new creativity would be unleashed? As we learn more about the mysterious tributaries activated in reading, perhaps there are more teaching strategies to be discovered, helping those who do not find it a natural activity, or for those around the world who miss out on early education.

AS I LEFT the Centre del Carme, I saw Xu Bing standing at the exit and asked him to sign my copy of *Book from the Ground*. He smiled and asked me to write the letters of my first name on a piece of paper before crafting them anew—not in a linear line, as an alphabetic system requires, but in a block, producing the effect of a Chinese character, another trick he has devised to disrupt our experience of reading, which he calls "square brush calligraphy." He signed his own name in an emoji: round-lensed spectacles. He also included two Chinese characters, though I couldn't tell whether they were from a Chinese dictionary or *Book from the Sky*, which he no doubt would have been pleased to know.

To me, the experiences of reading Xu Bing's various scripts feel vastly different. That's because I learned to read an alphabetic script and continue to read alphabetically all the time. Perhaps one day children brought up on emojis will learn to read a combination of pictures and letters just as fluently, returning us to the age of Egyptian, Cuneiform, or Mayan systems, where sound and pictures mixed to produce meaning together. Xu Bing reminds us that the way we read is not hard-wired into our brains but can be learned and re-learned. The way we write in the future may take on entirely new, now-unimaginable forms. The artist is now echoed by scientists, who offer one more piece of evidence to explain the success of our species: The superpower of our brain lies with its extraordinary ability to adapt to situations and challenges, bestowing advantages far more quickly than anything evolution can offer. ☺

LYDIA WILSON is a researcher at the University of Cambridge's Computer Laboratory, and a visiting scholar at the Ralph Bunche Institute at CUNY's Graduate Centre. She recently presented the BBC's series *A Secret History of Writing*, and edits the *Cambridge Literary Review*.

Time Flows Toward Order

Revisiting the gospel of the second law of thermodynamics

BY JULIAN BARBOUR



THE ONE LAW OF PHYSICS that virtually all scientists believe will never be found to be wrong is the second law of thermodynamics. Despite this exalted status, it has long been associated with a great mystery and a bleak implication. The mystery is that all the known laws of nature except one do not distinguish a temporal direction. The second law, however, asserts the existence of an all-powerful unidirectionality in the way all events throughout the universe unfold. According to standard accounts, the second law says that entropy, described as a measure of disorder, will always (with at most small fluctuations) increase. That's the rub: Time has an arrow that points to heat death.

Surprisingly, evidence that a more nuanced account is needed is hiding in plain sight: the universe itself. Very soon after the Big Bang, the universe was in an extremely uniform state, which since then has become ever more varied and structured. Even if uniformity equates to order, that initial state was surely bland and dull. And who can see disorder in the fabulously structured galaxies or the colors and shapes of the trees in the fall? In fact, the sequence in which two of the greatest discoveries in science were made resolves the paradox: The second law was discovered eight decades before the expansion of the universe.

The time lag is critical for one simple reason. The laws of thermodynamics, discovered in 1850 by William Thomson (later ennobled to Lord Kelvin) and Rudolf Clausius, emerged from a brilliant study that Sadi Carnot (son of Napoleon's greatest general) published in 1824. In a slim booklet that laid out all but one of the foundational principles of thermodynamics, he sought to establish the maximum efficiency steam engines could achieve. Steam engines can only function if their working medium is confined in a cylinder. This led all early work on thermodynamics to be based on systems in a conceptual box. Clausius's discovery and definition of entropy—one of the wonders of science—relied totally on infinitesimal changes from one equilibrium state of a confined system to another. The pioneers of statistical mechanics, the theoretical framework created above all by Clausius, James Clerk Maxwell, and Ludwig Boltzmann to provide a microscopic atomistic explanation of phenomenological thermodynamics, invariably considered models of gas molecules trapped in a box and forced to bounce off its walls and each other.

A rich conceptual framework, completely valid and immensely fruitful for confined systems, developed out of this simple model, and reached its definitive form in the work of J. Willard Gibbs. The model proved the existence of atoms and molecules, established their sizes, determined the incredible number of them in a grain of sand, and struck the death knell of Newtonian classical physics. That was when Planck discovered the first quantum effect in 1900. What's more, both the first and second law appeared to be founded on a rock-solid principle: the impossibility of creating perpetual motion machines.

It's therefore not surprising that few, if any, scientists have disagreed with the great astrophysicist Arthur Eddington's warning, "If your theory is found to be against the second law of thermodynamics I can give you no hope; there is nothing for it but to collapse in deepest humiliation." Einstein, surely a greater scientist than Eddington, was more cautious. A few years before his death, Einstein said of thermodynamics, "It is the only physical theory of universal content which I am convinced that, within the framework of applicability of its basic concepts, will never be overthrown." The

caveat is all important: Do conditions in an expanding universe remain within the framework of applicability?

That is what I question. I don't suggest we can ever alter the facts that Thomson and Clausius first brought to light. Neither you nor I are going to get younger or see a shattered cup miraculously reassemble itself and jump back onto the table. There is a pervasive unidirectionality, an arrow of time, about the way things happen in the universe. Kelvin, the first to recognize its significance, called it "a universal tendency in nature to the dissipation of mechanical energy." I don't deny the existence of the arrow, but I do suggest that the "box mentality" has led us to misunderstand what is happening in the universe and even blinded us to the beauty that it is creating. A one-way street need not lead to a scrap yard; it might bring us to a finely landscaped park.

Compare two situations. First, the molecules in their box. If, every now and then, you open it to look at them, you can be sure to find them filling the box uniformly and going through their habitual routine—bumping into each other with random outcomes. Nothing of interest develops. This, nevertheless, was the model used to interpret mundane measurements of pressure and temperature. It led to all those marvelous discoveries and much of the technology on which today we so depend. No wonder it inspired confidence.

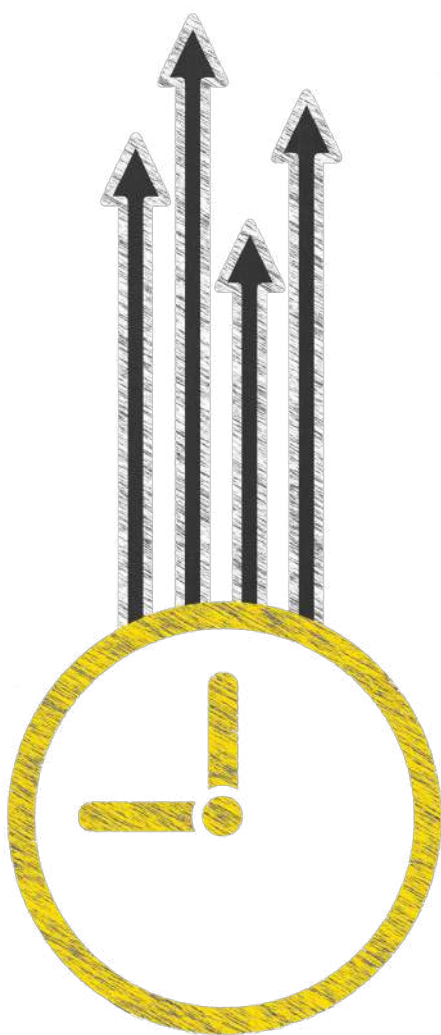
But now picture the box in space with its walls suddenly removed. What will the molecules do? The answer's in Siegfried Sassoon's poem "Everyone Sang":

As prisoned birds must find in freedom, Winging wildly
across the white

Orchards and dark-green fields; on – on – and
out of sight.

In mathematical rather than poetic terms, the molecules soon cease to interact and fly apart, maintaining forever their release velocities and getting ever further from each other. In fact, a simple calculation may surprise you: The speed with which the molecules move apart approximates ever better the law of galactic recession that Hubble announced in 1929. This simple Big Bang model does not look like disorder on the increase.

*I don't deny the arrow of time.
But the "box mentality" has
led us to misunderstand what
is happening in the universe.*



THERE IS A GREATER MISMATCH between entropic disorder and reality in the very heart of Newton's theory of universal gravitation. He achieved fame by explaining not only Kepler's laws of planetary motion but also the fall of an apple. However, the problem of three bodies—he had in mind the earth, sun, and moon moving in their mutual gravitational fields—gave him headaches. Although a famously difficult problem, in 1772 the great mathematician Joseph-Louis Lagrange made some progress, including a significant discovery about the behavior of a “three-body universe” that was later shown to be true for any number of bodies. It concerns what is now called the center-of-mass moment of inertia, I . This measures the extent of the system—for bees it would be about the diameter of a swarm—and behaves in a characteristic universal way if a single condition is satisfied: The total energy of the system is not negative.

To understand what the behavior is, assume with Newton that time flows forever forward from past to future. Then what Lagrange found is that I decreases from infinity in the distant past, passes through a unique minimum, and grows to infinity in the distant future. I call this unique minimum a Janus Point. The Roman divinity can be invoked because he looks simultaneously in two opposite directions of time at once. What he sees is striking. In the region around the threshold on which he traditionally stands, the distribution of the particles (especially when there are many) is more uniform than anywhere else on the timeline of the universe. Then, in both directions, the particles cluster, taking on a shape that is more ordered and forming “galaxies.” From his vantage point, Janus can see this, but if you, being a mere mortal, were in such a universe you would necessarily be on one or the other side of the Janus Point and could not “see through it” to the other side. You would find that the laws of nature around you do not distinguish a direction of time but that your universe gets ever more clumpy in one direction.

There is a precise, mathematically significant quantity that may be called complexity and increases (with small fluctuations) in both directions from Janus. The big difference from what entropy does is that growth of complexity reflects an increase of order, not disorder. The effects in confined and unconfined systems are the exact opposites of each other. Moreover, the increase of

complexity in unconfined systems follows directly from the governing dynamical law whereas entropy increases in confined systems for statistical reasons.

Traditional arguments assume that somehow, for an as yet unfathomable reason, the universe gets in a special state of low entropy and correspondingly high order that is then remorselessly destroyed. A model often given is molecules confined to a little box in the corner of a big box. That's the special initial condition. Now lift the lid of the little box; the laws of dynamics allow two quite different outcomes. It's conceivable, but barely so, that the molecules will collect in the corner of the little box and then be in an even more special state. But it is statistically more likely that the molecules will spread out into the large box and eventually fill it uniformly. This is a statistical explanation of the entropic arrow. Applied to the whole universe, a special initial condition of this kind has been dubbed the "Past Hypothesis" by the philosopher of science David Albert. The difficulty is that nothing in the known laws of nature explains the special initial condition.

LET'S NOW THINK ABOUT the Janus Point. It's unique and a special point. It isn't there for some inexplicable reason. Newton's laws say it must be there. Even if the weak condition on the energy is relaxed, something very like it in the form of a "Janus region" will almost always be present. The complexity will increase in both directions from it. The increase in order has a dynamical explanation and is what puts the direction into time. Moreover, beings on either side of the Janus Point would think they are going forward in time and would have typically the same kind of experiences, just as two people walking down opposite sides of Mount Fuji in Japan would find the terrain and vegetation change in much the same way.

Doubts about the repeatedly claimed growth of disorder in the universe get greater when we consider what happens when, as the particles emerge from the melee at the Janus Point—they are there typically going in all possible directions—some of them come together as "Kepler pairs." Except for encounters with other particles, which become exceptionally rare as the model universe expands and the typical distances between the particles become greater and greater, such pairs bond forever, settling down into

The beauty is in the ratios, and they persist forever even in the expanding universe.

The Janus Point resolves the mismatch between a law that does not distinguish a direction of time and solutions that do.

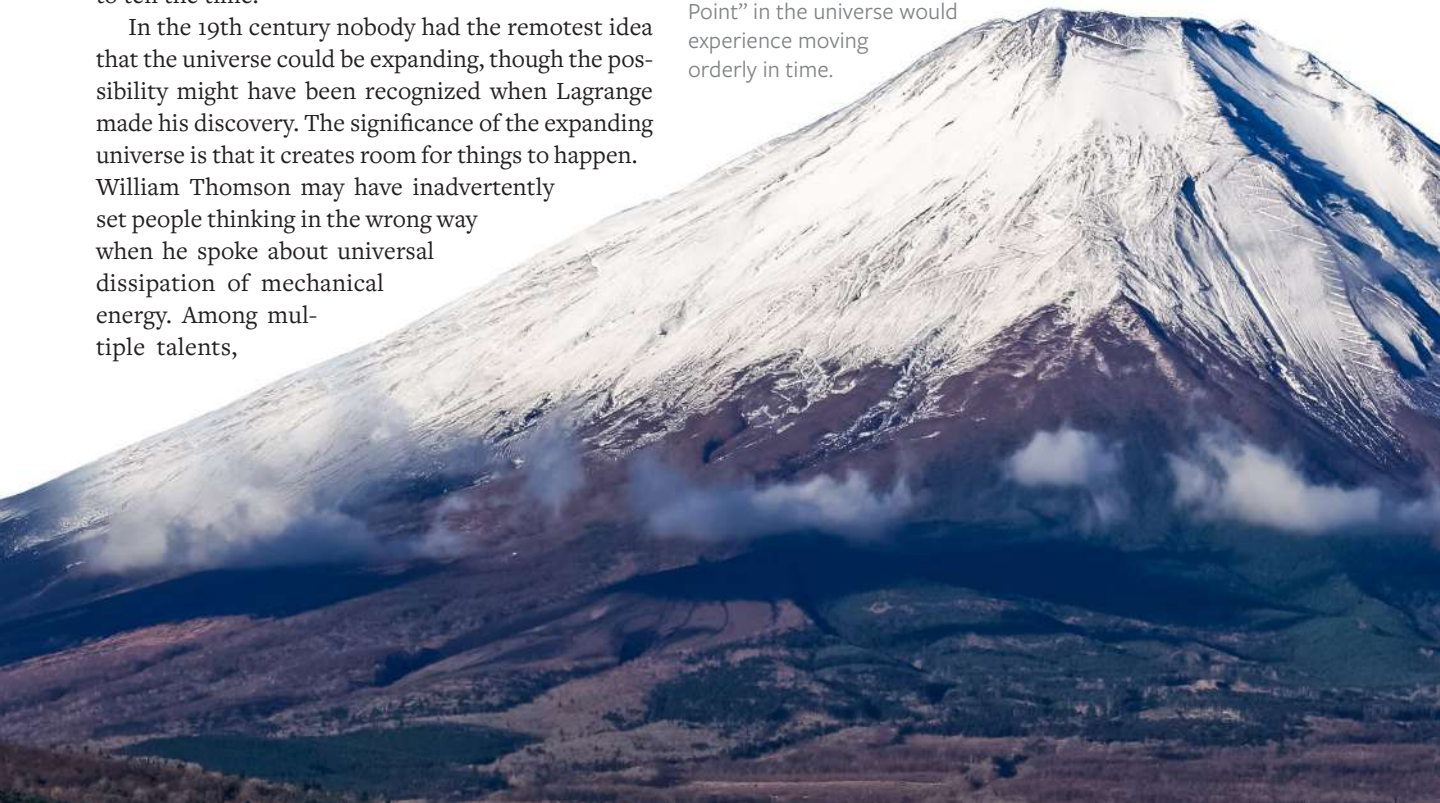
ever more perfect elliptical motion about their common center of mass. They form exquisitely accurate rods, compasses, and clocks all in one. Their major axis defines an astronomical unit of length and a fixed compass direction (true north), while the period of their motion defines a unit of time. Does that look like disorder?

William Blake hated Newton's clockwork universe, as it came to be known. The poet thought it was reductive, but that was based on the appearance of the solar system, which does resemble clockwork. In fact, Newton was so amazed by its beauty and order he could not believe his laws could explain its existence—God must have set it up that way and keep a careful watch on it to see the order does not get disturbed. In fact, Kepler pairs are miniature solar systems and Newton's laws create them out of chaos. His universe first makes clocks and then allows them to tell the time.

In the 19th century nobody had the remotest idea that the universe could be expanding, though the possibility might have been recognized when Lagrange made his discovery. The significance of the expanding universe is that it creates room for things to happen. William Thomson may have inadvertently set people thinking in the wrong way when he spoke about universal dissipation of mechanical energy. Among multiple talents,

he was a brilliant engineer and, like Carnot with his study of steam engines, was always looking for ways to improve the human lot. A negative connotation attaches to “dissipation”; had Thomson used the neutral word “spreading,” positive as well as negative possibilities might have been seen.

BOTH SIDES NOW Two people walking down opposite sides of Mount Fuji would see the terrain change in much the same way. To author Julian Barbour, the hikers' perceptions offers an apt analogy for how beings on either side of what he calls a “Janus Point” in the universe would experience moving orderly in time.



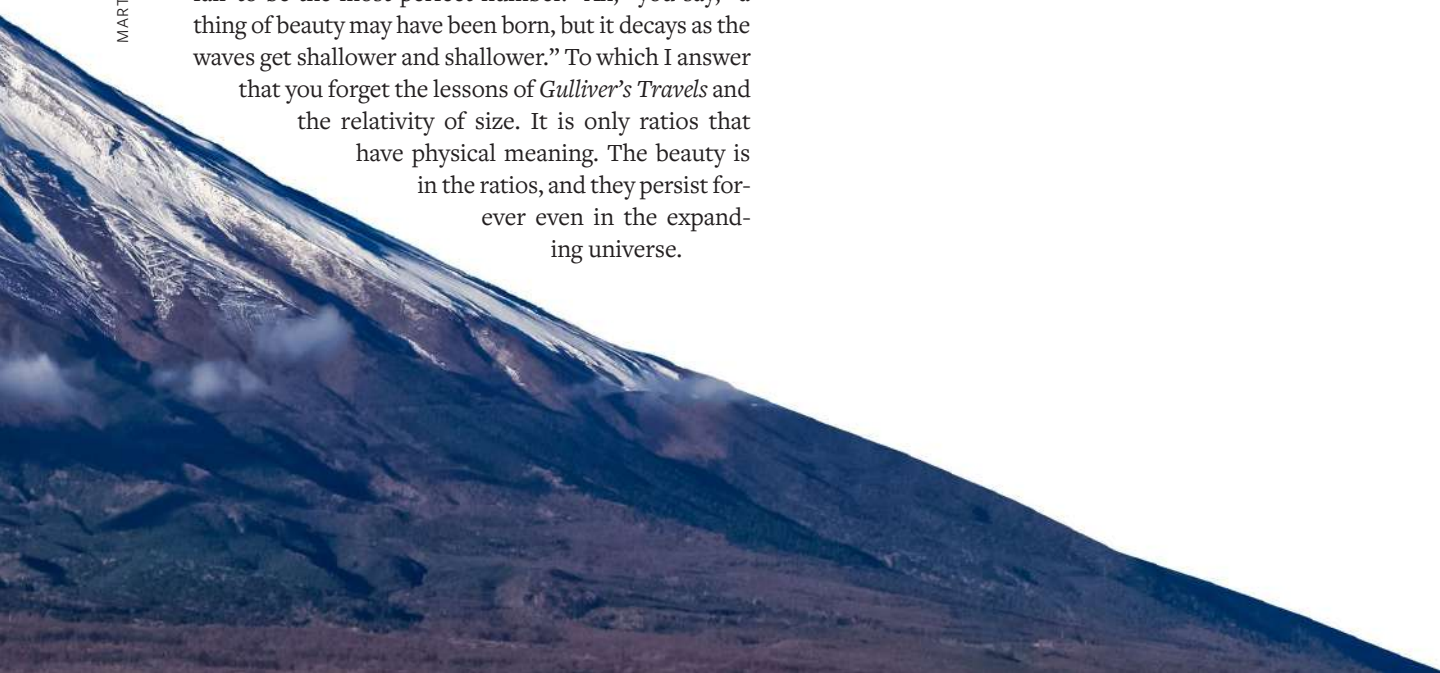
There is a beautiful effect I often go to watch on afternoon walks near my home. A tree hangs above a brook where the water flows smoothly over a ford. If it has rained, drops of water fall from the tree onto the water, creating circular waves that spread out over the flowing water. You can watch the effect for far too long if you need to get on with work. The waves created by drops that hit the water at different points meet and pass through each other, each emerging intact. If the brook had no banks and the water no viscosity, that would create the condition that radiation finds in the vast voids of our expanding universe, and the patterns would remain as beautiful forever. That's the difference between an open and a closed system.

Before the banks have their effect in the brook, mechanical energy is first entirely within each falling drop but is then spread out in the circular waves. Except at or near equilibrium, Clausius's entropy is a quantity difficult to define and measure; Thomson's dissipation is a qualitative effect that is both universal and easy to recognize. He mentioned the heat created by friction as an example of dissipation; the illustration has been endlessly repeated. But Thomson loved the river Kelvin in Glasgow and took his baronial name from it. He must have often seen water drops falling onto the river. If in the title of his 1852 paper, which was so influential, he had changed "dissipation" into "spreading"—it would have been a better characterization—who can say how that might have changed the interpretation of the second law, especially after Hubble's monumental discovery?

The circle is the most perfect geometrical figure and pi, which relates its circumference to its radius, bids fair to be the most perfect number. "Ah," you say, "a thing of beauty may have been born, but it decays as the waves get shallower and shallower." To which I answer that you forget the lessons of *Gulliver's Travels* and the relativity of size. It is only ratios that have physical meaning. The beauty is in the ratios, and they persist forever even in the expanding universe.

I will end by saying that the notion of the Janus Point, which resolves the mismatch between a law that does not distinguish a direction of time and solutions that do, might turn out to be less significant than how expansion of the universe can change the way we interpret the second law and look at the universe. I say this because the scenario I have described assumes that the size of the universe remains finite at the Janus Point. But it can actually become zero in Newtonian theory and does so typically in Einstein's general theory of relativity. That opens up extremely interesting possibilities that just might lead to a truly new theory of time. ☺

JULIAN BARBOUR is an independent theoretical physicist and past visiting professor in physics at the University of Oxford. His new book, *The Janus Point: A New Theory of Time*, is available from Basic Books.



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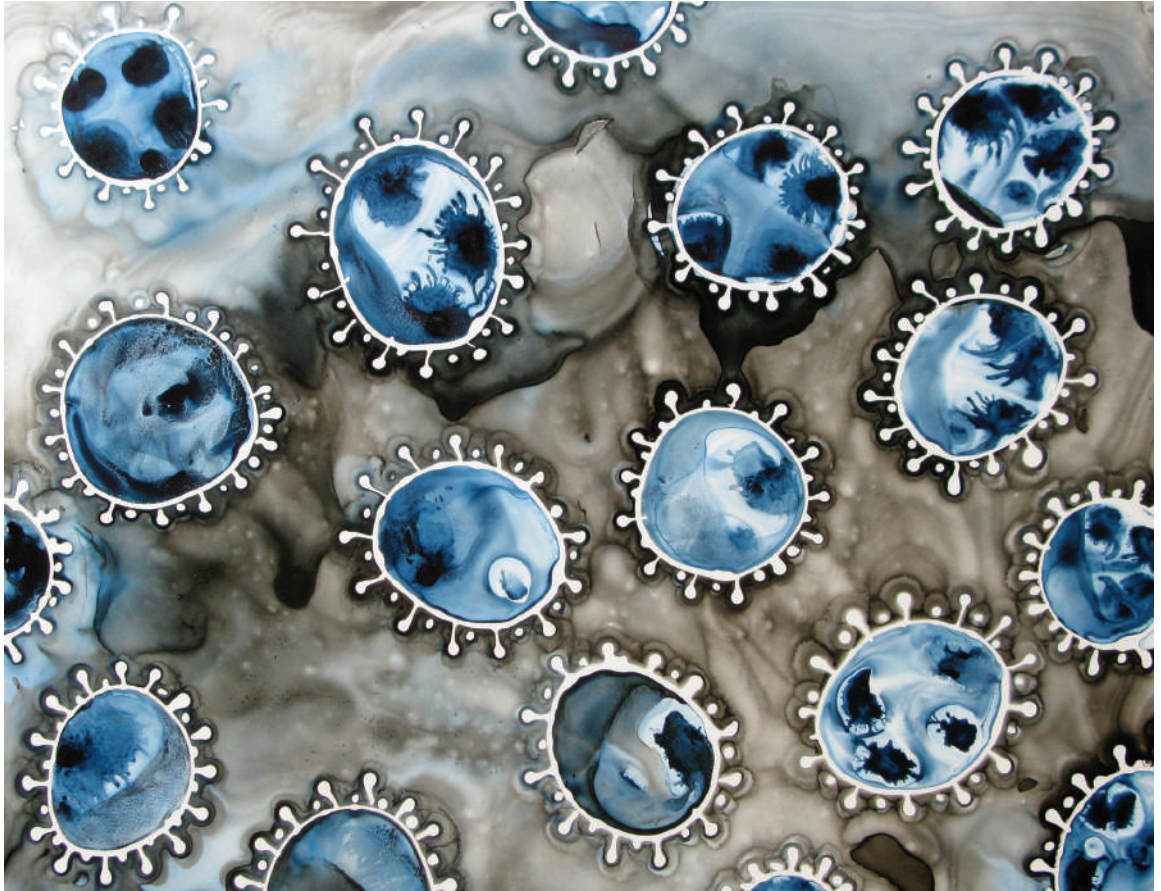
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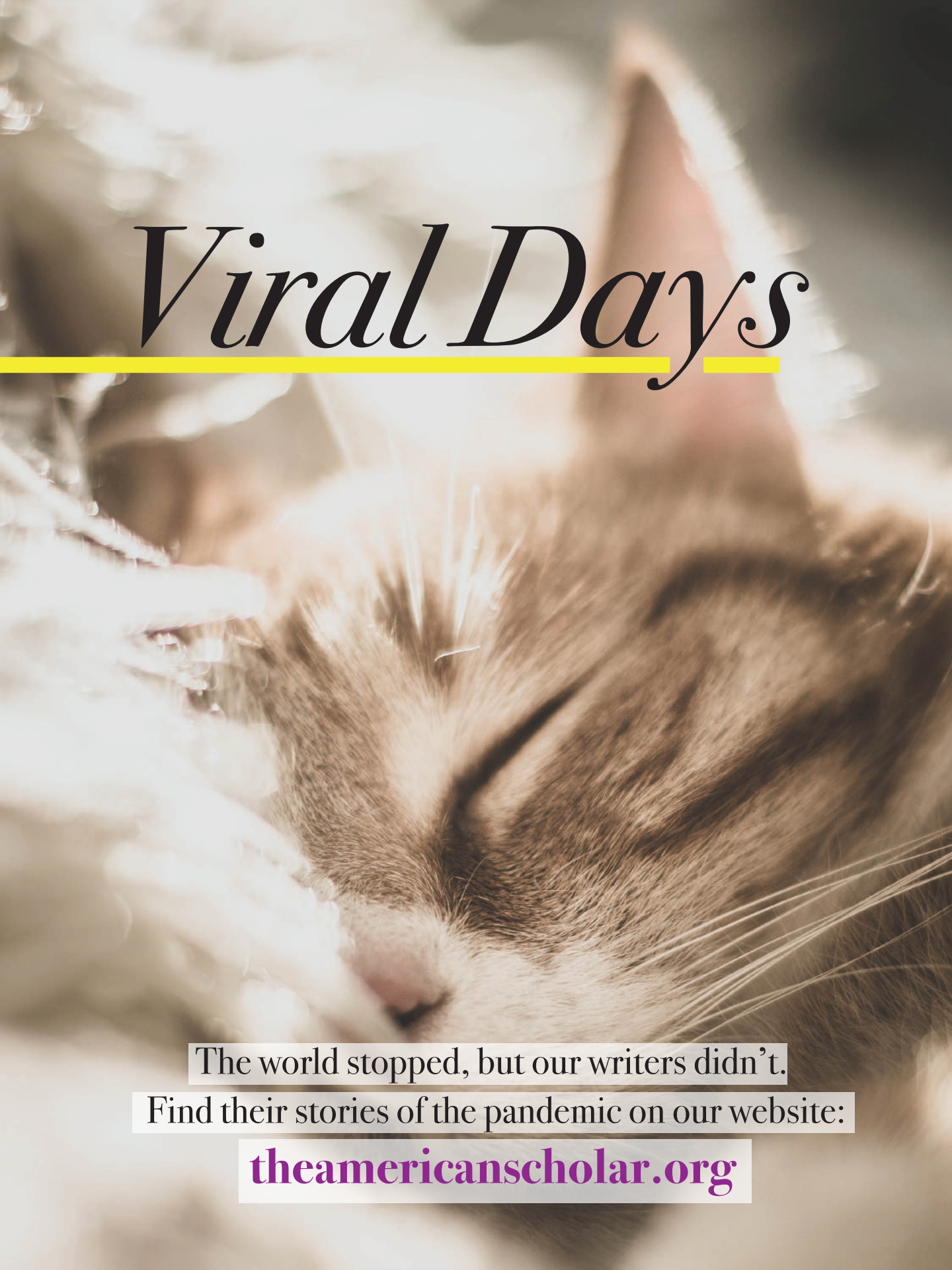
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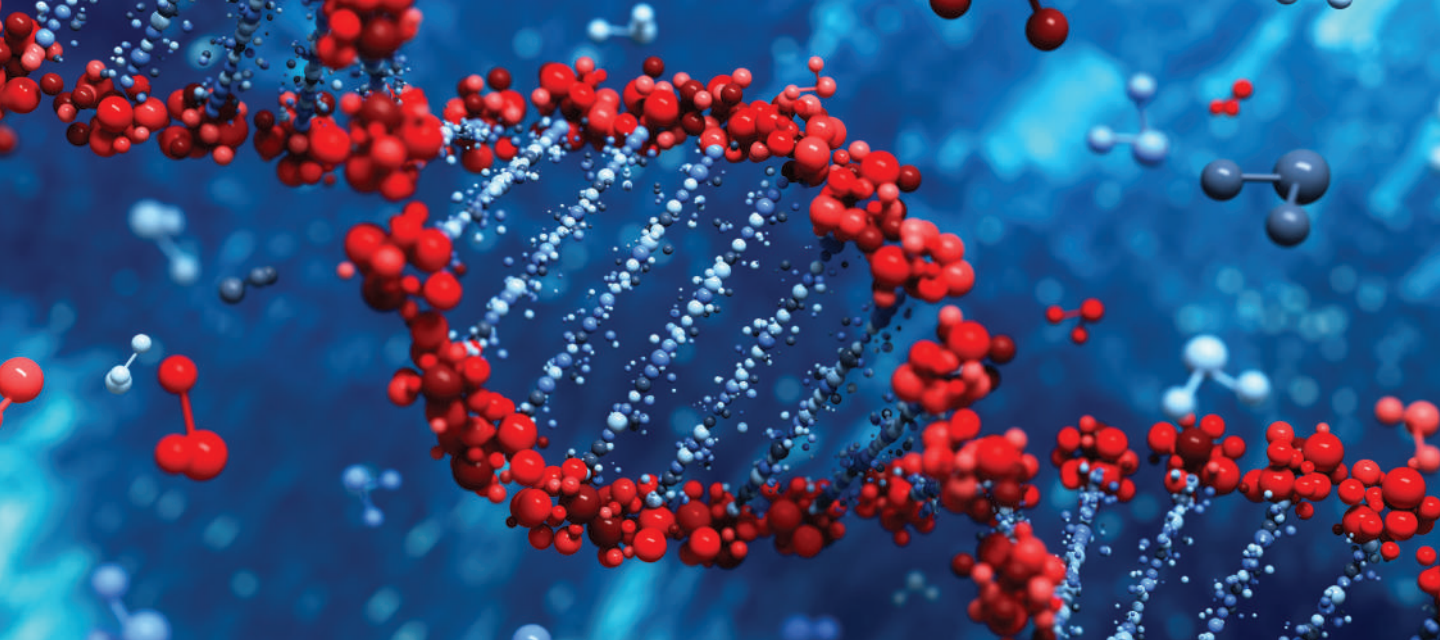
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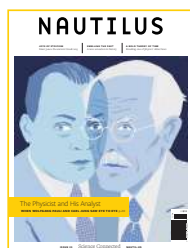


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Issue Index



35

2020

93 FORERUNNERS
94 EVOLVING



34

2020

90 SOMETHING GREEN
91 THE AMAZING BRAIN
92 FRONTIERS



33

2020

88 LOVE & SEX
89 THE DARK SIDE



32

2020

85 REOPENING
86 ENERGY
87 RISK



31

2020

83 INTELLIGENCE
84 OUTBREAK



30

2020

80 ALIENS
81 MAPS
82 PANPSYCHISM



29

2020

77 UNDERWORLDS
78 ATMOSPHERES
79 CATALYSTS



28

2019

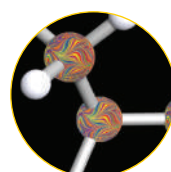
75 STORY
76 LANGUAGE



27

2019

72 QUANDARY
73 PLAY
74 NETWORKS



26

2019

68 CONTEXT
69 PATTERNS
70 VARIABLES
71 FLOW



25

2018

A SELECTION OF
STORIES FROM THE
APR - DEC 2018
ONLINE ISSUES.



24

2018

56 PERSPECTIVE
57 COMMUNITIES
58 SELF



23

NOV/DEC 2017

54 THE UNSPOKEN
55 TRUST



22

SEPT/OCT 2017

52 THE HIVE
53 MONSTERS



21

JULY/AUG 2017

50 EMERGENCE
51 LIMITS



20

MAY/JUNE 2017

48 CHAOS
49 THE ABSURD



19

MAR/APR 2017

46 BALANCE
47 CONSCIOUSNESS

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18

JAN/FEB 2017

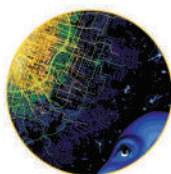
44 LUCK
45 POWER



17

NOV/DEC 2016

42 FAKES
43 HEROES



16

SEP/OCT 2016

40 LEARNING
41 SELECTION



15

JULY/AUG 2016

38 NOISE
39 SPORT



14

MAY/JUNE 2016

36 AGING
37 CURRENTS



13

MAR/APR 2016

34 ADAPTATION
35 BOUNDARIES



12

JAN/FEB 2016

32 SPACE
33 ATTRACTION



11

NOV/DEC 2015

30 IDENTITY
31 STRESS



10

SEP/OCT 2015

28 2050
29 SCALING



09

JULY/AUG 2015

25 WATER
26 COLOR
27 DARK MATTER



08

MAY/JUNE 2015

22 SLOW
23 DOMINOES
24 ERROR



07

MAR/APR 2015

19 ILLUSIONS
20 CREATIVITY
21 INFORMATION



06

WINTER 2015

16 NOTHINGNESS
17 BIG BANGS
18 GENIUS



05

FALL 2014

13 SYMMETRY
14 MUTATION
15 TURBULENCE



04

SUMMER 2014

10 MERGERS &
ACQUISITIONS
11 LIGHT
12 FEEDBACK



03

SPRING 2014

07 WASTE
08 HOME
09 TIME



02

WINTER 2014

04 THE UNLIKELY
05 FAME
06 SECRET CODES



01

FALL 2013

01 HUMAN UNIQUENESS
02 UNCERTAINTY
03 IN TRANSIT

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Daniel Levitin

*The neuroscientist and author of Successful Aging on
outwitting the Grim Reaper*

INTERVIEW BY KEVIN BERGER

BE ENGAGED

Successful aging is being able to continue to take pleasure from activities that have historically brought you pleasure, and being able to find new things that provide pleasure. It's being able to engage with life, with friends and relationships, and being able to make a contribution to the world—whether it's the way the Dalai Lama and Jane Goodall are doing it, or just the world of your own family.

BE UPBEAT

People who have an upbeat personality are more inclined to engage with other people. Other people are more inclined to want to engage with them. Nobody wants to be around a perpetual sourpuss. And social connections are vitally important to life satisfaction and successful aging. Loneliness has been associated with a greatly increased risk of premature death. It compromises the immune system. Upbeat people tend to explore the environment more. They learn new things and stay mentally challenged. They don't get into despair.

BE SOCIABLE

The neurochemical serotonin is responsible for mood regulation. If you're in a good mood and your serotonin levels are healthy, that's going to produce T cells, which are the James Bond of the immune system. They handle the most difficult cases. Many of us have cancerous tumors growing in us all the time, but our immune system gets rid of them. When the immune system is compromised, or cancer tumors evolve some kind of special mutation that makes them resistant to our immune system, you can end up with a malignancy. But being upbeat and engaged with life tends to increase serotonin. And being stressed,

which releases cortisol and adrenaline, for evolutionary reasons, turns off higher cognitive thought, digestion, and libido. In the short term, if you're trying to escape from a tiger, it's OK to shut down those systems. But you don't want them shut down chronically.

BE REALISTIC

Be optimistic but realistic. You get a big ugly black growth on your arm and you think it couldn't possibly be cancer and so you don't have it checked. That's too much optimism. False hope is tricky. If you're convinced you're going to die, and it sends you into a mental funk, depression and stress, that shuts down your immune system. If you're optimistic and think you can fight this, you may be able to tilt the balance. Somebody could say, "I've got a 20 percent chance of living with this for another five years. Screw this, I'm just going to make out my will and sit on the couch and eat bonbons until I go." But the other person would say, "20 percent? Maybe I can increase that to 30 if I do these things." And that's worth doing. You want to avoid the extremes of gullible optimism and fatalistic pessimism.

BE PREPARED

We shouldn't fear death. We need to prepare for it. If you're afraid of a traffic accident, you still have to drive. You wear your seatbelt, you make sure the car is in good shape, the tires are inflated. Employ the same kind of conscientiousness you do before a long road trip to your own aging process. Conscientiousness is unevenly distributed through the population, as are all personality traits. The good news is that even if you don't have a lot of it, or have too much of it and are obsessive-compulsive, you can change. You're never too old to change. ☺





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