

NAUTILUS

MIRROR, MIRROR
AI is not human at all

SURF'S UP
Riding the only wave with legal rights

STELLAR FAMILIES
How distant stars are related

The Kinship Issue
TIES THAT BIND



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The Kinship Issue

BY KATHERINE HARMON COURAGE

IN THIS ISSUE of *Nautilus*, we bring a new understanding of kinship—and how it can unite us, ocean waves, and even distant stars.

In the rainforests of Papua New Guinea, the Mali tribe has long practiced a valuable skill: building huge families. These aren't genealogies created through blood and marriage, mapped out into discrete trees. As the anthropologist Harvey Whitehouse discovered in his years of living with them, "they had the ability to conceptualize vast portions of humanity as one giant family ... related both physically and spiritually."

When a devastating tropical storm struck Australia, a well-resourced country more than a thousand miles away, the tribe, which had lean economic means, felt inspired to pool what they had and donate it to disaster relief. To the Mali, the Australians weren't former colonizers. They weren't even neighbors. "The way they spoke about it, the Australians were like family to them," Whitehouse writes, wondering if this radical disregard for geopolitical, economic, and historical boundaries could help illuminate a different way forward in a deeply fractured century.

A different wave has struck up an unexpected sort of kinship in Brazil. This fall, *Nautilus* associate editor Kristen French packed up her surfboard and brought it to a small fishing village on the Atlantic coast there, where a special ocean wave breaks—the first one in the world to be given personhood status. It now has its own right to existence, protected under law. The wave is opaque with sediment, polluted, hard to surf. But as one local anthropologist and surfer told French, it "brings to us this kind of request for listening ... to understand the language of nature," an effort to remind people they, too, are a part of the planet and its cycles.

On the flipside, some kinships we create can work against us. A propagating view of artificial intelligence as kin to the human brain seems to be eroding our sense of what's special about our own abilities to think and reason. As philosopher and AI ethicist Shannon Vallor explains to *Nautilus* contributor Philip Ball, large language models that employ artificial intelligence are superficial analogies to the brain. In fact, Vallor says, LLMs are more like "mindless toasters that do a lot of cognitive labor without thinking."

Also in this issue, we learn about what inspires animals to adopt, discover siblings among stars, uncover a shared language with plants, listen in on a conversation of big ideas between two scientists who share more than a name, and more.

It turns out, what connects us is bigger than we thought.

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THE PORTHOLE

Short sharp looks at science

PSYCHOLOGY

Yes, We Can Care About People Who Don't Exist Yet

IMAGINE YOU'RE HIKING, and on this sunny day, you see something glinting. Kneeling down, you realize it's a piece of glass, a buried broken bottle, exposed on the trail. You'd have to dirty your hands to dig it out, and you reason that if you don't, there's a fair chance someone—perhaps a child—could cut themselves badly on the shard. Feeling moved to save this person from that potential future pain, you throw the bottle away.

In *What We Owe the Future*, the philosopher William MacAskill offers a hypothetical scenario like this one to make the simple point that future people matter. “In deciding whether to clean it up, does it matter *when* the child will cut herself?” he writes. “Should I care whether it’s a week, or a decade, or a century from now? No. Harm is harm, whenever it occurs.” But do people really believe that, and if they do, do they have as much empathy for pain now as for pain still to come?

“We were interested in understanding if people actually buy that,” says Matthew Coleman, a psychologist at Northeastern University. And so, with his Northeastern colleague David DeSteno, he conducted a series of four experiments probing how people relate to others’ suffering in the future. Their results were published



in the journal *Emotion*, and I bet the findings would—if MacAskill were to read them—put an encouraging smile on the philosopher’s face.

Most of us have a present-bias. “We know that for our own well-being we systematically under-invest in our future,” says Coleman. “This is in part because we have this empathy gap between our present and future selves.” The gap could manifest in two ways: One is via future anhedonia, a forecasting bias that can lead people, for example, to predict that they wouldn’t be as happy getting, say, \$1,000 in a month versus getting it now. Another is intertemporal empathy decline, a tendency to care less for future suffering because empathizing with pain that doesn’t exist yet, a form of psychological distance, is harder.

In their first two studies, Coleman and DeSteno randomly assigned more than 1,000 participants—roughly equally split between men and women who were, on



People just don't care as much about future pain as present pain.

average, in their late 30s—to entertain a present or future scenario: Someone breaks their ankle now or 25 years from now, and someone suffers from respiratory issues now or 25 years from now. They found the same thing: “People do buy the argument that pain is pain whenever it occurs,” says Coleman. “They just don’t care as much about future pain as present pain.”

These findings could have real-world consequences. In another experiment, involving about 2,500 participants, Coleman and DeSteno told participants they would have an opportunity to donate as much as \$20 to a nonprofit and described an existing effective organization, the Clean Air Task Force, which combats pollution. The researchers then randomly assigned the participants, as with the previous experiments, to entertain a present or future scenario: that the nonprofit’s efforts would make a big impact for people living now or that it would have a big impact for people living 200 years in the future. How much of the \$20 would they donate, keeping the rest for themselves? (Coleman and DeSteno told the participants that five of them would be randomly chosen to have their donation preferences honored.)

Just like before, participants’ empathy for future people diminished: Those who were told their money would help the Clean Air Task Force better the lives of others living 200 years in the future chose to donate less compared to people whose money would aid it in benefiting others now.

If we care about investing not merely in our near future—the years ahead for those of us living now—but also the deep future enjoyed by people who have yet come into being, then these findings are some cause for concern. We may recognize that their experiences—their joys and miseries—are just as valuable as our own, and yet we seem less inclined to care about them in equal measure.

Coleman doesn’t think we’re taking threats to the lives of future people seriously enough. According to

a 2023 survey, the median risk expert predicted a 20 percent chance that a catastrophic risk to humanity (defined as 10 percent or more of everybody dying in a five-year period) would happen by 2100. “We seem to be under-investing in our collective future as a society,” he says, “with imminent problems like climate change and other technological advancements that pose risks.”

But there is hope: Coleman and DeSteno found, in another experiment with more than 1,100 participants, that vividly imagining the suffering of future people removes the intertemporal empathy decline effect. “In the real world, we want to address large global problems. Talking purely about the philosophical reasoning and the logic is important,” says Coleman, “but will fall short, because we need to address the emotional component as well.”

And that’s arguably where great art comes in. Powerful storytelling and poignant imagery, in artistic works like novels and films and video games, can transform our feelings toward issues and people we know nothing or care little about—either now or in the speculative future. “Making others’ well-being vivid and concrete and easy to imagine,” says Coleman, “is one strategy for increasing and marshaling care toward future generations.”

—Jim Davies

ARTS

Reviving Mayan Blue

LUIS MAY KU WAS INTENT on finding the plant. He felt certain that somewhere among the shrubs of his home village in Mexico or in the surrounding jungle grew the wild *ch’oj*. He needed the plant to extract indigo, a dye he could experiment with to unlock the recipe of “Mayan blue”—a pigment no longer available in the markets of the Yucatan peninsula, and a favorite color of the Mayan gods.

“There are five cardinal points in the Mayan cosmogony,” says May Ku, who is a ceramics artist and identifies as Mayan. In addition to north, south, east, and west, there is the



cardinal point that stands for the center of the Earth. “Its color is a mixture of blue and green,” May Ku says. “It holds the world together.”

A native of Dzán, a tiny village nestled in Yucatan, May Ku splits his time between home and Cobá, a renowned hub of classical Mayan culture, where a collection of pyramids—estimated to be some 1,100 to 1,500 years old—attracts tourists and scholars in search of the past. At Cobá, May Ku is the director of the local cultural center and a public school teacher.

“I started making faces of Mayan people who are currently living, who are in Mayan communities,” says May Ku. Practicing the *costumbrismo* style of art that focuses on the everyday, May Ku wanted to use the same colors as his ancestors. White and red were available from the local stores, but he coveted blue, in that sacred hue that “purifies, and heals,” he says. A millennium ago, it was used by Mayans to decorate objects as well as to cover the skin of people and animals during rituals. But all the blues that May Ku could purchase were synthetic. “I didn’t like it,” he says.

After years of scouring for clues far and near—the internet and his local environment—May Ku found a single *ch’oj* plant (*Indigofera suffruticosa*) in the backyard of the very cultural center where he worked. He confirmed with a botanist friend that this was the plant he was looking for. Deciding between cutting the plant down to experiment immediately and setting up a small grove, May Ku settled for the patient option. It took him a few months to collect the seeds, plant them, and nurture them before attempting to extract the indigo dye.

“Friends in Cobá lent me a piece of land” May Ku says, “and we took care of [of the seedlings] with a group of families. I told them that you have to put a lot of water on it, you have to water it, it has to be in the sun.”

Then he harvested leaves and soaked them in water for a full day; the leaves began to ferment. He shook this broth to aerate it, and the dye precipitated. If you were to soak clothes in the fermented water, they would first bleach and then begin to turn it blue, he explains. “This



practice was used by the ancient Mayans,” May Ku says, “to paint their clothes.”

But “Mayan blue is not just the plant,” May Ku says. The indigo dye is soluble and washes away quickly. To produce Mayan blue, it has to be heated together with special clay. “It is a local soil that combines with the plant, the molecular elements of the two tie up.”

Archaeologists and chemists studying Mayan artefacts dating to 700-1000 A.D. had determined that Mayan blue was indeed a composite pigment, binding organic and inorganic elements. Studies had determined that ink extracted from variants of *Indigofera suffruticosa* was likely mixed with either sepiolite or palygorskite clays in various combinations to produce a range of blue pigments used by Mayans, Aztecs, and other Mesoamerican tribes. Today it survives as color on parchment and sculptures from that period, having withstood the wear of time.

Scientists have attempted to reconstruct the traditional Mayan process of preparing the pigment because it is so durable, resistant to age, acid, weathering, biodegradation, and even modern chemical solvents. The description of this process is absent from surviving pre-Hispanic Mesoamerican codices. These are records containing images and text, dating to 1250-1521 that are considered the scholarly legacy of Indigenous history, religion, and astronomy of the region before colonial contact. But the chemical composition is meticulously documented



A SACRED HUE Mayan blue was used in ancient societies to decorate objects and color images, and to purify the skin of people and animals in rituals. It was considered the color of the gods. Luis May Ku now uses it to decorate sculptures crafted in a traditional style, like the one shown here.

through spectroscopy and other techniques, using synthetic variants of Mayan blue and original scripts for using to color images, such as mythical creatures, human-like figures, flowing water.

May Ku set up a makeshift lab to try to recreate the pigment at home. He fermented the *ch'oj* and combined the ink with clay by experimenting in various ceramics techniques. The day he first saw a pigment that resembled Mayan blue, he says he was “ecstatic.”

“Mayan blue is born from a combination of trial and error,” says May Ku, and “I was able to arrive at this method ... the closest to the pre-Hispanic way of how to do it.” Two separate laboratories, in Italy and in Mexico, confirmed that the chemical composition of the pigment he produced is analogous to the variety used by his Mayan ancestors a millennium ago, says May Ku.

In the end, the secret was in the local clay. “I don’t share its name,” says May Ku. Thanks to his efforts, after a thousand-year hiatus, a trade in Mayan blue has resumed in Yucatan. The land had kept the tradition all along.

—Elena Kazamia

ZOOLOGY

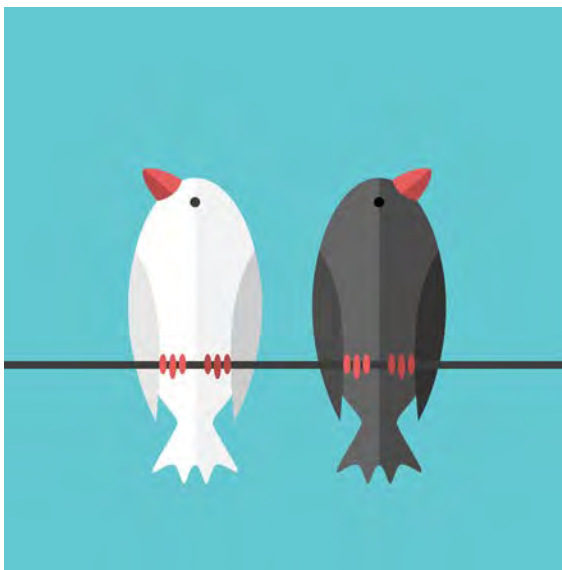
When Songbird Couples Split

ON THE SEYCHELLES ISLANDS in the Indian Ocean, little greenish-brown warblers mate for life—or at least a substantial part of it.

Year after year, male and female bring the young chick insects to eat while vigorously defending the nest from skinks or predatory birds. These pairings are remarkably stable, lasting up to 15 years—a good chunk of their lifespans, which can reach 20 years—with just under 7 percent of warbler couples separating every year on average.

But scientists are finding that changes in climate can upset these harmonious partnerships. In a recent study in the *Journal of Applied Ecology*, a team of scientists discovered that in years with little rainfall or extremely high rainfall, divorce rates soared, sometimes more than doubling to 16 percent.

Researchers suspect these higher rates of divorce may be driven by the stress brought by food scarcity in years with harsher climate—a conclusion that may bode ill for the little birds’ partnerships in a world



with increasingly variable rainfall. But scientists are still working out whether higher warbler divorce rates are necessarily a bad thing in the long run, or if they might even help the birds adapt to adversity. In the worst case, “it could have long-term effects on the population size,” says evolutionary biologist Hannah Dugdale of the University of Groningen in the Netherlands.

Since 1985, researchers have been carefully monitoring warblers on the Seychelles’ Cousin Island, catching them every year during the breeding season; each bird carries a metal ring with a unique identifier around its leg, along with a unique combination of colored rings so they can be identified with binoculars. The program is so thorough that if a bird isn’t sighted in a year, “we know that it has died,” Dugdale says. The bird couples are very territorial, so if one of them disappears from its territory and reappears in another, it’s clear that it has separated from its partner.

The reality is that males and females are sexually promiscuous and often cheat on one another, but once pairs begin to share a nest, the male will still stick with his female mate to care for her offspring—even when the chick is not his. The bird couples typically live together with helper birds—usually the female’s older offspring, both male and female, who help them in raising young. Female helper birds sometimes also breed and contribute an egg to the nest.

Scientists don’t know much about exactly how warbler divorces play out—when it happens, whether it’s the male or the female initiating the separation, or if it’s preceded by a period of strife or aggression. “Maybe one just leaves without saying anything. It could be a very sad affair,” says behavioral ecologist Augs Bentlage of the University of Groningen, a joint first author on the paper with his colleague Frigg Speelman, also at the University of Groningen. After splitting up, some birds stay single while many find new partners.

The warblers’ average annual divorce rate of 6.6 percent per year is comparable to that of other birds that tend to live out their lives in a single region but lower than that of many migratory species that have much higher annual divorce rates. For great reed warblers, for instance, it’s 85 percent. That’s partly because partners lose each other over long seasonal journeys and end up finding new mates along the way.

Seychelles warbler divorce rates were highest in years with unusually low rainfall, according to the team’s analysis of divorce data and local weather records. Bentlage suspects that dry weather reduces the vegetation that insects feed on and evaporates waters where the insects lay their eggs. Warbler couples would then struggle to find enough insects for their offspring, causing physiological stress. The birds may blame these difficulties on their choice of partner, the researchers hypothesize. “You might actually start to perceive your partner as being a low-quality partner,” Bentlage says. On top of this, male helper birds appear to be less likely to assist with chick-raising in years with low rainfall, while females didn’t change their behavior, according to previous research by Dugdale and her colleagues.

The year of 1997, which saw exceptionally high rainfall in the Seychelles, also saw a spike in warbler divorce rates. Extreme rainfall can kill insects while strong winds can destroy bird nests. And if birds get wet, it’s harder for them to maintain optimum body temperatures. Parents would need to stay with chicks to help keep them warm, limiting their time for insect-gathering, causing stress. From low to high rainfall, “both extremes kind of have the same effect,” Bentlage says.

It’s still unclear what all this means for the warbler populations overall. Extreme years in the Seychelles are



If divorce is causing warblers to break up with perfectly good mates, they may wind up single or with worse partners.

predicted to become more common as the global climate warms—a trend that is already making the birds less likely to attempt to breed and lay an egg as well as lowering fledgling survival rates, probably because there are fewer insects for them to eat.

Divorce could either help or hurt the birds during harsh years. Separation could counterintuitively be a good thing if the birds are indeed ditching partners who are bad at finding food, for instance. This might give them the chance to find ones who are better at

it, giving future chicks a higher chance of survival. In line with this idea, some long-term research on black-browed albatross couples has found that when they divorce—which increases in years with warm sea surface temperatures—the females tend to find new partners with whom they're more likely to produce chicks.

But, if divorce is causing warblers to break up with perfectly good mates, they may wind up single or with worse partners instead. This could, in turn, lower the number of chicks they make and, theoretically, over many generations, even increase extinction probability, Dugdale says.

Either way, it's clear that the heating of the Earth's atmosphere has not only obvious and direct impacts on animal survival, but also more subtle and complex influences on their lives, the decisions they make, and the relationships they cultivate with one another.

—Katarina Zimmer

ENVIRONMENT

Plagues, Taxes, Storms, and the Jet Stream

A FEW YEARS AGO, Valerie Trouet, a tree scientist from Belgium, began to notice something curious. When her summer holidays at home were marred by cold rainy days, countries like Greece and Italy in the Eastern Mediterranean appeared to be battling unseasonal droughts and heatwaves. The reverse seemed to also be true—hot dry summers in Belgium and the British Isles coincided with cool wet weather in southeast Europe. Trouet started to wonder if the jet stream, that narrow current of air that encircles the globe, had anything to do with it.

Jet streams are concentrated bands of wind in the upper atmosphere that form at different latitudes at the boundaries of global air masses. The most powerful streams travel around the polar fronts, where warmer air meets colder air from the Arctic and Antarctic regions. In the north, the position and shape of the jet stream is determined by the intensity of high- and low-pressure weather systems that form seasonally over the European continent. Most of the time, the jet

stream flows in more or less a straight line, keeping colder pressure systems to the north and warmer pressure systems to the south. But in some years, the shape can slacken or elongate into waves, forcing cold and wet conditions southeast into the Mediterranean and pushing warm weather to northwest. (A similar bipolar dynamic exists between Southern California and the Pacific Northwest.)

As she dug into the research, Trouet learned that many climate models suggest this northern continental jet stream is becoming wavier with ongoing climate change, a trend that can increase the frequency of simultaneous extreme weather events at opposite ends of the continent, including heatwaves, droughts, floods, and wildfires. If the models are accurate, such extremes could result in frequent harvest failures in many parts of the continent at once. But many of these climate models rely on data collected after the 1980s, when satellite-based observations became more widely available.

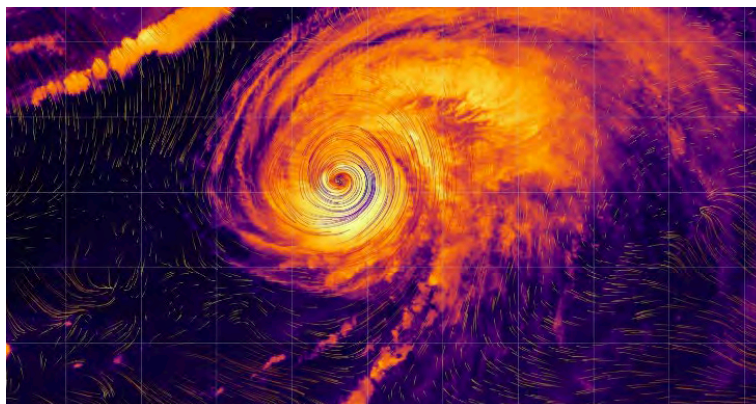


To get a better sense of long-term jet stream and climate patterns, Trouet decided to team up with historians and climate scientists. In a recent publication for *Nature*, she and her team unveiled a model for jet stream variability that extends the record by 700 years. By studying tree rings, Trouet and a team of paleoclimate experts produced a reconstruction of summer weather extremes for the period from 1300 to 2004 A.D. They then examined historical records to see how these weather patterns were reflected in records of storms, plagues, and harvests dating back to the Middle Ages. The researchers believe that what they found suggests a causal link between jet stream anomalies and such seemingly disconnected events as wildfires in Greece and Turkey, the spread of plagues in Ireland, and increases on wine taxes in Medieval Hungary.

"It was a non-stop treasure hunt," says study co-author Ellie Broadman, a tree ring and paleo-climate scientist now working at the Western Ecological Research Center in California.

To reconstruct historical jet stream patterns, Trouet and her colleagues relied on trees from three locations: the Scottish Highlands in the northwest, the European Alps, and Bosnian pine growing in the southeastern Mediterranean. Tree cores were studied for their "maximum late wood density," which shows up as a dark line that separates tree rings. The color, shape, and chemical composition of this dark edge depends on late summer weather. Years heavy in drought and heatwaves result in darker and more irregular lines. "We also looked at fire scars" Broadman says, "where you can count on which years there was a wildfire."

With the help of historians, Broadman and colleagues were also able to uncover data about the frequency of plagues, storms, and fluctuations in crop prices within their regions of interest in the southeastern and northwestern corners of Europe. Each time, they were chasing after simultaneous observations. "And it was either a null response or the expected response for everything we looked at," says Broadman.



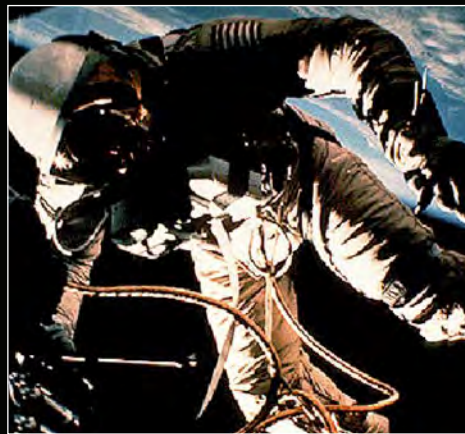
In Medieval Britain, they found that plagues spread faster when summers were, according to their models, unseasonably warm, when both fleas and humans were on the move. In those same years, vine crop failures and higher prices on wine were recorded in the Balkans, likely due to colder temperatures. Historic records of grain prices from the Netherlands, Belgium, and the British Isles for barley and wheat also suggested rates of crop failure were higher during years when tree ring reconstructions indicated unusually cool weather.

"While there is no super satisfying way of going back in time and saying, 'Certainly I can tell that these things are causally linked,'" Broadman says, "I take confidence in the sheer number, the sheer variety of totally disparate records and totally different time periods and types of documents," that confirm the correlations. "It seems too much to be a coincidence."

For the moment, climate scientists remain in disagreement over whether the jet stream will get wavier or shift latitudinally with ongoing climate change. "There's a broad range of opinions," says Rachel White, a professor of atmospheric science at the University of British Columbia, who was not involved in the study. Much remains to be discovered about what drives the jet stream, White says.

Still, Trouet and her colleagues say their results suggest we should take fluctuations in the jet stream into account when considering future climate change-related risks, including global food security. Seven hundred years of data is worth considering.

—Elena Kazamia



ASTRONOMY

Hello! Is Anybody There?

THE HUMAN URGE TO CONNECT is so powerful that we seek it even when confronted with the dark void of space, when there is no assurance that intelligent life exists. In 1977, NASA rocketed two copies of the famous Golden Record into the cosmos with the Voyager spacecrafts, our attempt to communicate across that void. The 12-inch, gold-plated phonograph discs are made of copper and loaded with images and sounds from Earth, hand-picked by a committee led by Carl Sagan. The record's contents, like a snapshot in time, describe what we thought life on Earth was all about 50 years ago.

Instructions, provided in symbolic language, explain the origin of the Voyager spacecraft and how the record is to be played. The recording itself includes natural sounds, such as surf, wind, and thunder, musical selections from different cultures and eras, and spoken greetings in 55 languages, including Akkadian, a language used to communicate in Sumer about 6,000 years ago. The records also contain 115 images: sprinters, vertebrate evolution, continental drift, the solar spectrum, an x-ray, a violin. A selection of those images are shown in the grid here.

The Voyager probes have transcended the boundaries of the solar system and are now traversing interstellar space, making them the most distant human-made probes still in operation. But their plutonium-powered hearts will not beat forever; as their cores weaken, the mission team is turning off the probes' instruments one by one to save energy. The Golden Records' attempt at cosmic connection will be their final mission.

—Mikael Angelo Francisco

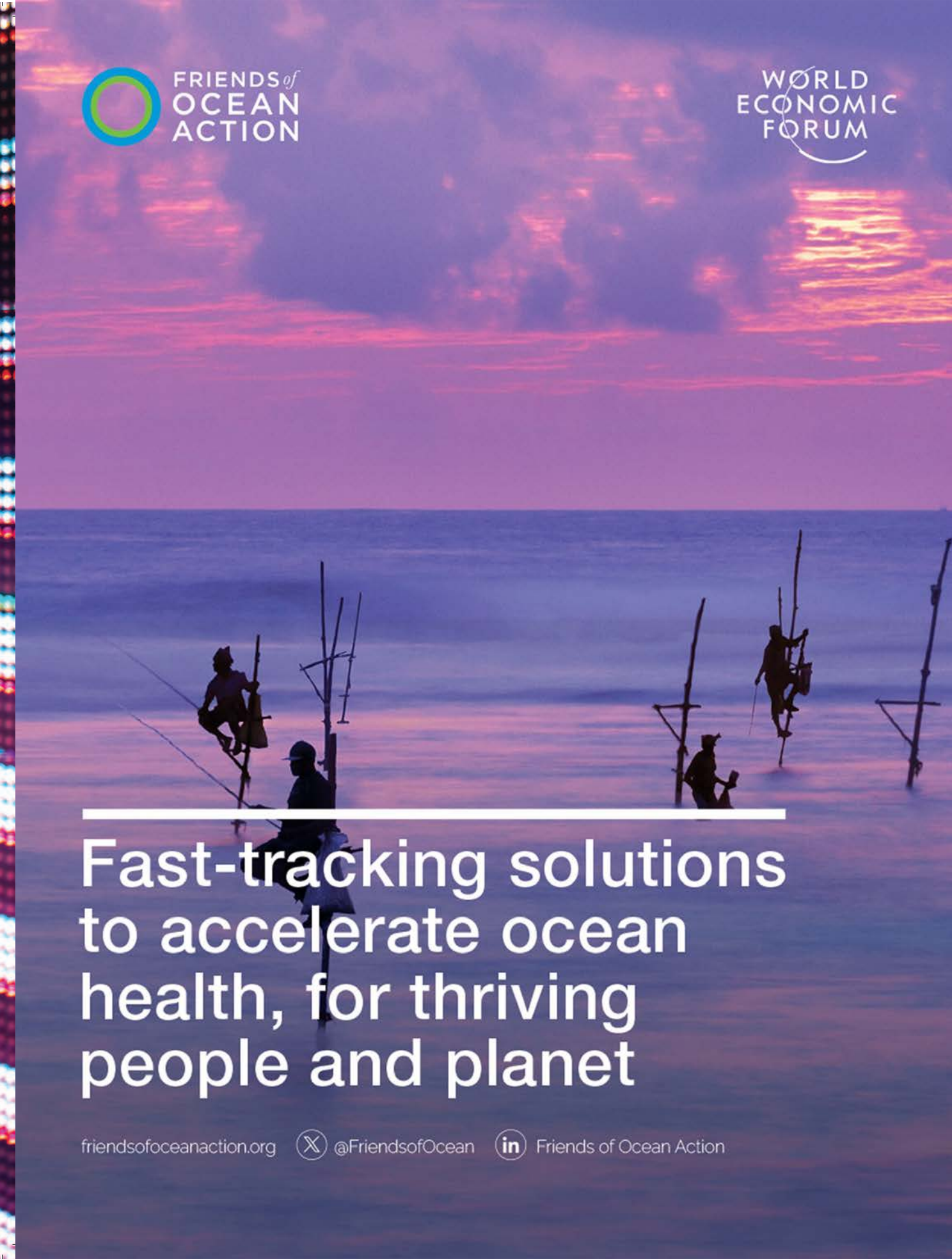
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The Kinship of Minds

BY KATHERINE HARMON COURAGE

CONNECTIONS AMONG MINDS are the spark that ignites science. The best thing is, they happen in the damndest places. On a university campus in the 1960s, one such connection started something like this:

Rosemary: “Those skis are too short for you.”

Peter: “No, they are not.”

Rosemary: “Yes, they are, I can see by just looking at them.”

The science it ignited lit a fire under contemporary evolutionary biology. By 1973, Rosemary and Peter Grant were married and in the Galapagos Islands together studying Darwin’s famous finches. They would spend decades there, observing. Their results, detailed in their own book *Forty Years of Evolution*—recently rereleased in a new and expanded edition—and retold in journalist Jonathan Weiner’s Pulitzer Prize-winning book, *The Beak of the Finch*, stunned the world by revealing that evolution is not just the slow work of aeons, but is happening right in front of our eyes. New birds would pair up, cross species, create hybrids, and almost as if by magician’s sleight of hand *poof!* a new species.

Now in their 80s, the Grants continue their work together, collaborating with colleagues overseas to parse new evolutionary detail from finch DNA. Weiner recently sat down with them again—this time instead of over a rocky field site in Ecuador, over tea at the Grants’ home in Princeton—to discuss their legacy of ideas, intertwined (you won’t find a separate Wikipedia page for either scientist, just a joint one for the two of them) spinning a web forward.

Intellectual kinship can also bubble up in far less predictable dyads. One contemporary philosopher, Helen De Cruz describes how she has

recently found it in communion with an ancient Chinese philosopher named Mengzi. “I asked him questions and requested his help,” she writes. Her conversations with him evolved her own understanding of virtue and goodness, leading her to see how, even in fraught times, “we can be ambitious in what we hope and strive for.” Now, that’s a good friend to have.

In the pages ahead, we also meet two scientists who found this connection thanks to a fluke of parental choice. Sean Carroll the theoretical physicist and Sean Carroll the evolutionary biologist share more than a name. They are both at the forefront of their fields, big thinkers who are also driven to connect science to story and the world. The fact that they are also both authors of numerous popular books about science has caused no small degree of confusion at lectures (“People bring me your books to sign,” one Sean Carroll tells the other Sean Carroll). *What if—we mused one day—we got the two Sean Carrolls together for a conversation?* So we did!

Who said kinship had to be earnest?

It turns out that when two Sean Carrolls walk into a conference room, we, the audience, get a front-row seat to the power of science to build on itself and connect seemingly disparate ideas. In the spark-filled conversation, their shared convictions—around complexity in the universe, the nature of religion, and how to instill hope in younger generations—span the vast difference of their upbringings and scientific pedigrees. At the same time, their lively differences crack open new views of the universe. And crack them both up.

We’re delighted to be in intellectual kinship with you. ☺

ILLUSTRATION BY AAD GOUDAPPEL

How Big Is Your Family?

Living with a Papua New Guinea tribe in the '80s presented this anthropologist with a question for today

BY HARVEY WHITEHOUSE



I**N THE SPRING OF 1987**, I stooped over the desk in my shared student office in Cambridge, England, running my finger across a map of Papua New Guinea and squinting at the tiny typescript. I was trying to establish the location of a cluster of tribes in the rainforest known as the Baining. Only one of those tribes was known to anthropology; the others were a mystery. As a young Ph.D. researcher, my ambition was to make friends with people as culturally different from me as it would be possible to find anywhere on the face of the Earth and to ask if I could live with them for two years.

After a very long series of flights and an arduous trek through the rainforest, I finally came face-to-face with the Mali—one of those elusive Baining groups I had been dreaming about. To my surprise, the Mali were much more like me than I could possibly have imagined. It wasn't just that they had the same basic material needs and wants, but they also shared with me—and my compatriots back in England—fundamentally similar moral concerns, supernatural inclinations, loyalties and rivalries, as well as a deep appreciation of music, dance, and other art forms. Nevertheless, the Mali also had a great deal of knowledge and wisdom that was new to me. For one, they knew how to build very large families.

By large families I don't just mean that they had lots of offspring—which was indeed true of many households in the village. What I mean is that they had the ability to conceptualize vast portions of humanity as one giant family, descended from common ancestors and related both physically and spiritually. Now, more than 35 years later, in a world increasingly torn apart by destructive regional conflicts and forms of polarization, I cannot help wondering if the wisdom of the Mali could help us to rethink the way we manage cooperation in the 21st century.

THE MALI LIVED ON A TROPICAL ISLAND roughly twice the size of Wales, studded with mountains and active volcanoes and blanketed in jungle. They built their houses in small clusters around a village clearing of well-trodden earth. They used timber from the surrounding forest to create uprights and rafters, strips of interwoven bamboo for the walls, and long strands of grass to thatch their roofs.

They fed themselves on tubers and fruits grown using methods of slash-and-burn horticulture, supplemented by the meat of domestic pigs and fowls as well as bats, snakes, marsupials, and wild boar hunted in the forest. Some people grew coffee or copra to sell for small sums of money to traders. The fate of such crops was a mystery to their producers. Clearly you couldn't eat the stuff. But the coins you received in return were very useful. You could buy bush knives and axes, which were more efficient at cutting down trees or butchering animals than traditional stone tools. But money also had another use. It could bring you closer to your ancestors.

I soon realized that families were more than just groups of living relatives. They encompassed a multitude of invisible spirits of the dead, who moved among us, taking an active interest in our comings and goings. As one of the leaders in my village put it, "The eyes of the ancestors see all our thoughts and deeds, and the things we say. The ancestors can sometimes discern observances and violations of the law, even though we are not aware of what we are doing" (my translation).

THE MALI On the left; an Indigenous group in Papua New Guinea, in a ceremonial dance.

It seemed quite incredible anyone could mistake me for an ancestor. I was possibly the most incompetent person in the village.

The ancestors were thought to see into our hearts and minds and evaluate our behavior, as well as to observe everything we said and did. Every day the people in my village left out offerings of food and water in special temples so that the ancestors would come to eat and drink. When the spirits of the deceased gathered in this way, they were said to form the “village government.”

The village government comprised hundreds, possibly thousands of ancestors. Many were loved ones and remembered fondly—mostly victims of common diseases like malaria, which continually claimed people’s lives. But many were also remembered only by name, being from generations long past. The members of the village government loved them, and their living descendants loved them in return.

But the village members were always letting them down through their sinful ways. Somebody would forget to perform the right ritual, teenagers would sneak off to have sex in the forest, a man would promise to help his cousin in the garden and then fail to turn up. The ancestors saw it all. And that’s when money became most useful. There were special receptacles in the temple, where people could place the coins they had accrued from selling crops, and in return receive forgiveness for their sins.

This practice was inspired by Catholic missionaries. On his occasional visits, a priest would conduct a

Mass and hear confessions in the village, but nobody believed his rituals did any good. People humored him out of politeness, but they knew that the real way to their ancestors’ hearts was through the temple rituals.

One day, the ancestors—gratified by the acts of devotion bestowed upon them in the temple rituals—would return from the dead and our giant family would be reunited. When this happened, it was said that the ancestors would have white skin and straight hair, just like the British, Germans, and Australians who had colonized New Guinea, bringing with them unfathomable wealth and technology.

As a young white man with passionate anti-racist convictions, I was horrified to learn about this dogma. For me, the obvious remedy was to eliminate the association between white skin, power, and wealth by establishing a more equal society in which all skin colors would be regarded with equal respect and pride. But for my Mali friends, the solution was to become one with the colonial invaders by themselves becoming white.

It was said that the returning ancestors would be rich beyond compare. And they would share this wealth with their descendants who, in turn, would peel off their earthly skin, and the many wounds and scars acquired from hard living, to discover unblemished white skin beneath. Then all of us would enjoy a period of eternal peace, health, and prosperity together.

DANCE OF THE ANCESTORS

"When I first danced wearing this costume—in a ceremony to honor the group's ancestors—I carried a long cane to demonstrate my ferocity," writes author and anthropologist Harvey Whitehouse.



The entire community fell silent. “So, you were sent to us by the village government?”

The community I lived with frequently gathered in the village meeting house, to discuss how best to strengthen our bonds with the ancestors and hasten the miracle of their return. Sometimes people would ask me questions about England and listen in astonishment to my tales about the rituals of my college in Cambridge—especially the strange rules relating to dining etiquette, such as the wearing of gowns, saying grace in an ancient language, and passing the port in one direction only.

People wanted to know if the food was laid out in the same way as in our village temples? Did all the paintings on the walls around the dining hall depict our ancestors? Why was King’s College Chapel so big? How many ancestors did the college have? Sometimes people would ask me probing questions about why I was sent to live with the Mali. How did I acquire the seemingly endless supply of money in my pockets?

I explained that my doctoral research was funded by a grant from the Economic and Social Research Council—public funds, raised from taxes. There was no other way to explain this in the local language than to use the word “government.” But as soon as I uttered it, I realized I had been misunderstood. The entire community fell silent. “So, you were sent to us by the village government?” asked one of the elders.

Later, one of my closest confidants told me of a rumour that my presence in the village was a sign. “A sign of what?” I wanted to know. He said they believed

I was an ancestor, and this was a portent that more would follow. It seemed to me quite incredible that anyone could mistake me for an ancestor. I was possibly the most incompetent person in the village when it came to almost anything of importance: gardening, hunting, cooking, or even speaking properly. “And what do you think?” I asked. He paused, apparently mulling it over. “I think you are an ancestor,” he said at last.

BECOMING AN ANCESTOR was one way of joining the Mali family—albeit rather unusual and not without its drawbacks. Another way was to be initiated into the tribe. I first learned about this from one of the elders, who had become used to my endless questions about the arts of warfare and raiding, how to catch pythons without getting killed, or which kinds of magic were needed to find a lost dog. When I started asking about initiations, his voice dropped to a whisper.

Most of what he told me involved the secret techniques for making dancing costumes and masks. But two aspects of his account became lodged in my memory more firmly than the rest. One was that the red coloration on the masks should be created by lacerating our tongues and spitting out the blood to use as paint. The other was that we should have penis extensions fastened to us by a belt secured at our back by sharpened bones driven through the skin at the base of our spines.

When my time came to be initiated, I got off lightly. I was put through a sanitized version of the rituals, in which red paint was used instead of my blood and my dancing costume was secured by a knot, without having any sharp objects thrust into my body. But even though I was spared the most painful elements, I will never forget the pride I felt when I danced before the entire community, along with the other initiated men dressed in all our finery. I was part of the Mali family—whether or not I was also one of its progenitors.

Then one day there was a terrible storm. As high winds and torrential rain swept through the village, some of us huddled together in the meeting house, trying to keep the fire going. People began to tell stories about tropical storms, and someone mentioned the time that a cyclone hit Australia, to the south of us.

Stories about Australians whose houses had been destroyed had traveled far and wide. To my astonishment, I learned that the people in the community and hundreds of others like it throughout the rainforest had been so appalled to hear of the suffering of their “brothers and sisters” in Australia that they decided to donate much of the money they had collected in their temples to help victims of the storm.

Nobody seemed to realize that their rich neighbors in Australia were mostly well insured or that their emergency services were well equipped to help them get through the disaster. Or maybe it didn’t matter. The way they spoke about it, the Australians were like family to them. And when family is in need, you do what you can. That’s what family is for.

I returned to Cambridge in the fall of 1989, and I was soon back at my desk surrounded by books. But I found myself frequently reflecting on this extraordinary act of generosity and especially the idea that family could be extended to include people from other cultures one will never meet and even to the dead who may one day return. As an anthropologist, I had read many theories about kinship, but none of them seemed to capture exactly the ways of thinking I had encountered in the rainforest. It gradually dawned on me that kinship boiled down to the sharing of something essential to oneself with other people.

This special “something” could be some feature of your body. Where I grew up in England, we talked about shared blood among family members. In other

places it might be bones or even something intangible like the Polynesian concept of *mana*—the spiritual power or life force associated with heritable positions of high social status. But however we conceptualize it—and whatever we call it—this essence is something we inherit from our ancestors. It connects us to them and to each other.

This is how we create tribes based on shared descent—and how we create the idea of ethnic groups whose shared ancestry is passed down in the form of traits we can see on the body. My family in the rainforest connected themselves in this way to me and even to people in Australia they had never met. This helped me to understand better their belief that we all share the same skin underneath.

But there was another way of sharing essences with other people. This way involved sharing something in the mind rather than in the body. It involved sharing experiences and memories that were essential to your autobiographic self, your sense of who you were as a person. That’s how the initiation rituals worked. They created memories of emotionally intense, life-changing experiences that were shared with other members of the group and with their ancestors.

If the tribe members in Papua New Guinea were capable of using these same methods of group-bonding to help people in faraway countries, then maybe they could teach us how to tackle cooperative problems on an even larger scale. By realizing that we are indeed one global family—descended from common ancestors—perhaps all of us may be capable of the same acts of generosity. ☺

HARVEY WHITEHOUSE’s new book is *Inheritance: The Evolutionary Origins of the Modern World*. He is an anthropologist and the director of the Center for the Study of Social Cohesion at the University of Oxford.



This Ocean Wave Has Rights

The true meaning of legal protection for nature

BY KRISTEN FRENCH



IN A BLAZING MORNING in October, I paddled my surfboard into a caramel-colored sea off a beach in Brazil, hoping to catch a wave with its own individual rights. The wave rose up against the wind as if in greeting, its perfect peak of foam resembling the enigmatic smile of a new friend.



THE ALCHEMIST Hauley Silva Valim shows off a bowl of iron shavings from a display in an open-air studio at his home. On the table, he has arranged lines of objects he decorated with mining dust, as well as tiny finger bowls with medicinal herbs and books about alchemy.

As I sat on my board in the waves, I watched other surfers, many of them young kids, crouch and ride in perfect sync with the swell. That morning, the size of the surf was small—about three feet high from the base—but the lip was steep. Looking over the edge, I felt a flush of vertigo. Many advanced surfers have snapped bones here because the wave is heavy and breaks in shallow water.

I paddled toward the peak preparing to ride, but kept hesitating at the crucial moment. The wave was much faster than I am used to, and I was having trouble getting out of my head. Finally, I made the drop, but I lost my balance and the

wave pounded me into the sand, the churn of the white-water in my ears. The cycle repeated. I needed to figure out what the wave was trying to say.

Under a local ordinance signed in August 2024, the wave is now considered a person in the eyes of the law. It has the intrinsic right to existence, regeneration, and restoration and to the natural flow of the river that feeds it. With the help of human advocates, it can bring cases against those who harm it. It's a small victory for the growing rights-of-nature movement around the world.

The wave runs along a four-mile stretch of beach that is bounded to the north by a 500-mile river called the Rio Doce, or “sweet” river, and to the south by a turtle reserve. Just behind that beach sits Regencia Augusta, a small fishing village and weekend tourist destination for Brazilians with one grocery store and a population of a little over 1,000. Regencia is still recovering from what is often described as the worst environmental disaster in Brazil's history, the collapse of a mining dam on the Rio Doce nine years ago.

EARLIER THAT MORNING, I met former surf pros Robson Barros and Fabricio Fiorot on the beach. Barros and Fiorot are both active in the local surf association, which played a major role in getting the new law passed. They were joined by their sons, lanky, long-locked surfers who bopped around restlessly on the sand, eager to hit the water. Almost 30 years ago, Fiorot told me, he moved to Regencia “for a dream.” He wanted to live in closer communion with the wave, which locals insist is Brazil's most perfect barrel, the ultimate draw for many surfers. In the right conditions, it forms long hollow tubes that embrace the ready athlete in a rhythmic knot, forming a kind of human-ocean chimera.

People in Regencia divide time in two: before the mud and after the mud.

When Fiorot and Barros moved to the village, which sits at the end of an 18-mile dirt road, many thought the wave was just a legend. Then a slew of wave-check websites emerged online and began providing details of specific conditions at different breaks around the globe. Suddenly, there was proof for outsiders that the wave was real. “And from there, *Vwwwoooosh!*” Fiorot made an explosive motion with his hands. The area earned the nickname Tubolandia, land of the barrels, and *primos de Bali*, which translates as “cousins of Bali,” another barreling surf paradise. Surfers started coming from all over Brazil and even from places as far away as Australia.

But just as quickly as it had begun, the surf scene—and their entire way of life—collapsed. “The mud destroyed it,” Fiorot said.

In November 2015, a mining wastewater dam for an iron ore mine in the state of Minas Gerais failed, burying an entire village, killing 19 people, and pouring a tsunami of over 1.7 billion cubic feet of toxic mud into the Rio Doce, equivalent to about 21,000 Olympic swimming pools. The sludge polluted the water supply for more than 1 million people across 35 cities; decimated entire populations of fish; killed birds, amphibians, and mammals; destroyed native vegetation; and flattened the homes of nearly 600 people.

Some 16 days after the collapse, the waste reached the sea, and a giant plume spread hundreds of miles out into the ocean and along the coast. The water outside Regencia turned a deep shade of rust. Vultures

descended on the beaches to pick off the dead fish. Fishing, swimming, and surfing in the affected waters were prohibited. Barros moved to a city three hours south and wasn’t sure he would return. Fiorot shut down the surf school he ran and never reopened it. Tourism evaporated. As mining waste built up along the bottom of the river and at its mouth, the force of the river was nearly extinguished. It stopped moving torrents of water into the ocean and sediment into the seabed. The wave lost its perfect primordial shape.

In the years since the dam broke, one of the biggest biomonitoring programs in Brazil has employed a corps of some 500 researchers from universities around the country to monitor the impacts of mining waste on the region. Despite billions of dollars reportedly dedicated to cleanup efforts, these researchers report that the entire Rio Doce basin and many of the creatures who live in it remain contaminated with heavy metals such as lead, copper, zinc, arsenic, mercury, cadmium, and chromium, often at levels that are well above legal limits and toxic to health.

Even the blood and urine of humans living along the river have been found to be contaminated with heavy metals. Fiorot said researchers tested his blood in 2016 and found it heavily polluted with arsenic. There seemed to be no sense of when it might be safe to fish here or drink the water again, or whether it was even safe to surf week after week, year after year—though many do. Today, people who live in Regencia divide time in two: before the mud and after the mud.

At a bend in a dirt road, we slowed to a stop for protestors who aimed to block big corporations.

An anthropologist, theologian, surfer, and self-proclaimed alchemist, Valim explained that the Regencia wave is more than just a surfer's dream. "The wave brings to us this kind of request for listening, to listen to the language of nature—to understand the language of nature, which is enabled by the silencing of the human mind," he said.

Valim was one of the primary architects of the law to protect the wave, which was signed into law by the municipal legislature of Linhares, the municipality to which Regencia belongs. Granting rights to the wave comes from a "philosophy of regeneration, a principle of liberation," he said. "Water should run free."

The day was hot and humid, and we sat together in an open-air room next to his garden, which looked like a cross between a lab and an art studio. We were joined by Hanna Ayres Burnier, a yoga teacher and practitioner of Ayurveda, a holistic medicine. Burnier, whose parents live in town and operate an inn and artisanal brewery on the beach where I was staying, was translating from Portuguese for me.

On a small table, Valim had placed a tablecloth, also dyed apricot, and on top of that he had arranged several tidy lines of objects: a small bowl of iron shavings,

various rocks that represent different forms of mining waste, round tiles decorated with black iron glaze and beautifully stenciled ceramic bowls featuring the same pale peach color. He had been making art out of mining waste, he told me, turning the fine grains into dyes for pottery, recycling it into beautiful objects that he then used to teach kids about pollution and regeneration in nature.

Valim said the new law could help liberate the wave and the river that feeds it from threats posed by local extractive projects—not just ongoing contamination from the dam break, but also from hydroelectric dams and paper plants that are diverting Rio Doce flow, and from future ocean drilling platforms, which had been proposed off the coast of Regencia in the past. About 40 other mining dams in the Rio Doce watershed are also reportedly at risk of collapse. But it may be some time before the law is ready to be tested in court—a committee still needs to select the five guardians who will act as the wave's representatives and enforcers and be responsible for proposing public policies to support the law.

Still, rights-of-nature laws are riding a wave of cultural momentum. The movement began in the 1970s with an essay titled "Should Trees Have Standing?—Toward Legal Rights for Natural Objects," by American law professor Christopher Stone. Stone wrote that the history of law has followed the arc of human moral development, described by Charles Darwin in *The Descent of Man*. "Originally each man had regard only for himself and those of a very narrow circle about him ... then 'his sympathies became more tender and widely diffused.'" The rights-of-nature philosophy shifts the value of nature away from its ability to provide resources for extraction to its capacity to sustain life.

Rights-of-nature laws have taken root worldwide, especially in South America. In 2008, Ecuador became the first country to write rights of nature into its constitution. The amendment makes specific reference to the Indigenous Quechua concept of *sumak kawsay*, or "plentiful life," which advocates for taking only what you need from nature and nothing more. Since then, the constitutional court has decided several cases in favor of rights of nature and against the interests of industry. The most significant case is that of Los Cedros, a protected cedar cloud forest in the tropical Andes of northwestern Ecuador. In December 2021,



NO SWEET RIVER Daily life in the Indigenous community of Aldeia Areal de Linhares used to revolve around the Rio Doce, but that connection was severed after the mining dam broke and the river became polluted. Pictured here are Areal residents Augusto da Silva, a former fisherman from the town, José Souza de Barcelos, its spiritual leader, and Carlos Gil Monteiro da Silva, the chief of the community.

after a long legal battle, the judges in a constitutional court upheld the forest's constitutional rights to "exist, survive, and regenerate," annulled a mining concession that had been granted to two-thirds of the forest, and ordered restoration of any damages.

Over the past two decades, more than 140 rights-of-nature provisions have been implemented around the world. Many individual laws now recognize the rights of rivers such as the Ganges River in India and mountains such as Mount Taranaki in New Zealand. In Colombia, the Supreme Court recognized the Amazon

rainforest as having legal subjecthood and ordered the government to develop a plan to reduce deforestation to zero. And in Bolivia, a universal declaration recognizes rights for the entirety of Mother Earth, described as a "community of interrelated beings." That declaration sets forth that no distinction should be made between "organic and inorganic beings," such as a rock or a wave.

Environmental lawyers say that full implementation of these laws would require a fundamental shift in many domains of law. But Mauro Figueiredo, a Brazilian

environmental lawyer and surfer who has been working in coastal conservation for decades, told me the new law needs to have time to flourish, to spread the word. Brazilians need to “understand that taking care of other living beings, they are taking care of themselves,” he said. “Because it’s not just recognizing the intrinsic value of nature, it’s having a very strong ecological literacy within the community.”

Valim sounded similar notes. The Regencia wave is a way to teach people about the fundamental connections between the elements of nature—not just river and ocean, but also currents and tides and the motions of celestial bodies that govern them. Giving the wave “personhood” is a powerful reminder that humans are part of nature, too. It has emotional and storytelling appeal that could change minds and influence behavior. It’s “like raising a flag,” Valim said.

VALIM HAD PUT ME IN TOUCH with one of his mentors, José Souza de Barcelos, the spiritual leader and guardian of plant knowledge and healing practices for the Indigenous community of Aldeia Areal de Linhares, a 10-minute drive inland from Regencia. The community identifies as Botocudo, an Amazonian hunter-gatherer tribe who lived primarily in Minas Gerais and were originally named for the wooden disks they wore in their lips and ears.

After lunch, Burnier drove me to Barcelos’ place. At a bend in a dirt road, we slowed to a stop for about a dozen adults and children gathered under some trees. They aimed to block corporations, such as Brazilian energy giant Petrobras, from using the road. The blockade was part of a larger series of protests happening throughout the region. The reasons were many, but the primary one seemed to be that the



government had, just that week, made an out-of-court agreement with mining companies responsible for the 2015 dam break without consulting the people who were affected. (They weren't consulted in 2016 either, when the first agreement was signed.) With a smile, Burnier told them where we were headed, and they nodded and let us through.

When we arrived a few minutes later, we sat on Barcelos' spare concrete porch in plastic chairs while he called two others on his cell phone to join us. Barcelos has a broad handsome face and dark hair lightly flecked with gray and spoke quietly. He was wearing a T-shirt emblazoned with the logo of Projeto Tamar, a turtle conservation project that works in the reserve just south of Regencia. Soon the *cacique* or chief of the community, Carlos Gil Monteiro da Silva, arrived wearing a brown-and-blue feather headdress, a tropical flower print T-shirt and jeans. He had short, cropped hair and a crisp but friendly demeanor. He was followed by Augusto da Silva, a former fisherman from the town. (Augusto and Carlos are unrelated.)

The community of Areal considers the Rio Doce a living being, like a cherished family member. Before the dam break, learning to swim, fish, row, and hunt in the river, and to identify plants on the riverbanks used in traditional medicine, were all central to local identity. But the river is now off limits to them, and the catfish, mullet, seabass, and other fishes they used to catch are too dangerous to eat. Many herbs found on the banks of the river as well as fish bones used in traditional medicines have also been lost after the mud.

The spiritual relationship to the river was "100 percent severed," Barcelos said. "If you cannot drink the river water, if you cannot swim in the river, if you cannot fish in the river, there's no way to relate to the river." The river has become "a source of fear," added Augusto da Silva. After the dam break, they would find fish stuffed with mud in their guts, and the kids who

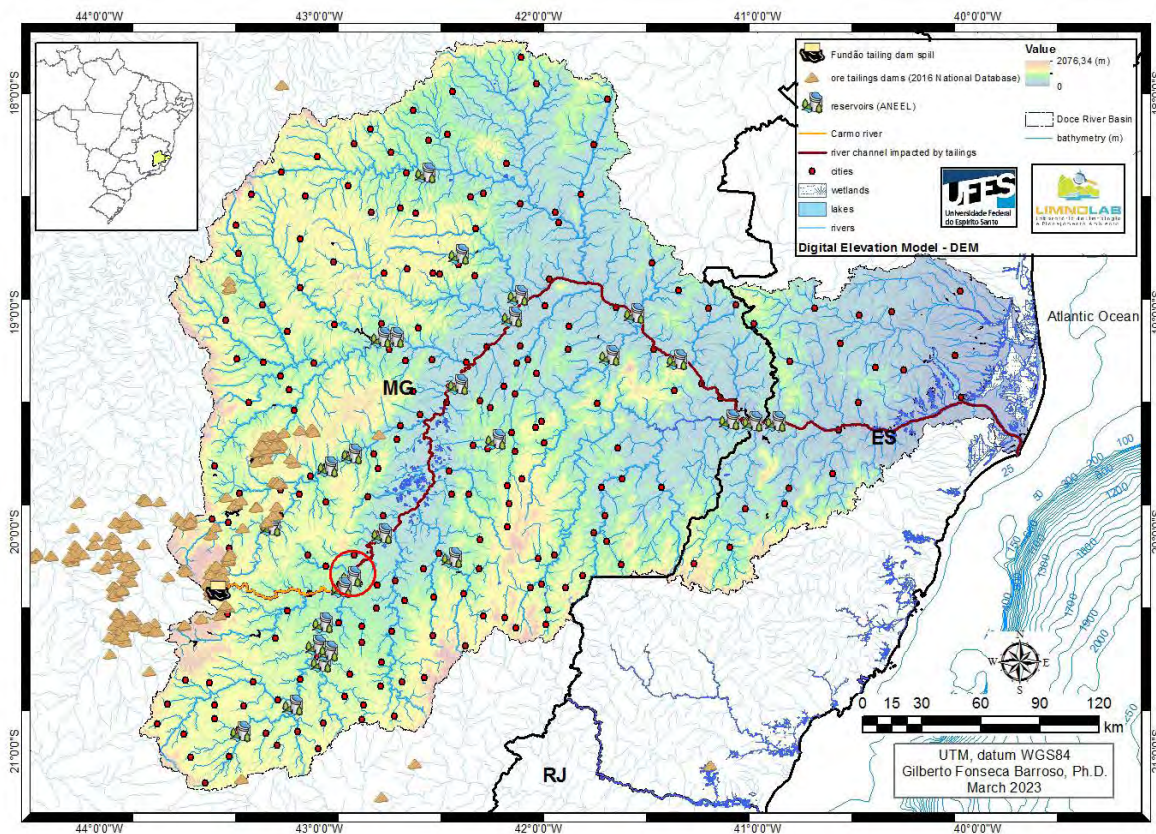
snuck into the river's waters would develop itching all over their skin. Augusto used to make a living as a fisherman, but now they cannot fish at all, so he works insecure day jobs at a cacao plantation or in construction.

To fill the hole left by the poisoning of the river, the community is trying to revive cultural traditions that do not rely directly on the river—such as congo, an Afro-Brazilian musical and spiritual tradition—particularly for the kids. But they are also open to adopting what Monteiro da Silva called the "culture of the wave." This culture is new to them because the ocean lies seven miles downriver from Areal, and they do not often find reason to go there, he said. But "even in the river, there are wavelets," he said, making a motion with his hands, and these wavelets are an expression of the same fundamental forces that govern ocean waves.

When I asked if the new law empowering the wave would benefit his community, Carlos da Silva said he believed it could, by helping to restore and protect the river, bringing visibility to those who live along it, and even leading to programs that provide the community with resources for surfing. If given the chance, a new generation of Indigenous kids might become expert surfers of Regencia's waves, and this might "take them away from drugs and bad choices," he said. "We understand there must be a union of cultures."

NOT FAR FROM WHERE the wave breaks in Regencia lies a hatchling ground for endangered leatherback, loggerhead, and green turtles and I learned that these turtles, too, have an intimate connection to the waves. October is the height of turtle nesting season, so one night, José Cerri from the turtle conservation group Projeto Tamar, which has been operating here since the 1980s, offered to show me the turtles' terrestrial home. Over the past five years, he told me, researchers have been recording changes in the turtles' health.

THE MINI IRONS (Left) A group of young kids in the town who compete regularly in surf contests call themselves the "mini irons," to reflect the fact that they surf in water polluted with heavy metals. One of them, pictured here with the colorful board, is 12-year-old Ana Gabriela Pessoti Dagostini. She has been surfing with her dad in Regencia since she was 3 years old and is happy about the new law. She has her sights set on becoming an Olympian, but plans to stay in Regencia, next to her favorite wave.



A RIVER RUNS THROUGH IT A map of the Rio Doce river basin, showing the location of the 2015 mining dam failure as well as the serpentine path in red of the Rio Doce winding to the sea, all of which was impacted by the mining sludge. The map also shows dozens of other mining tailing dams upstream of the Rio Doce in the state of Minas Gerais, which are reportedly at risk of failure, and the many cities, reservoirs, and wetlands along the river's route that were affected by the dam break.

Tissue and blood samples taken from turtles, unhatched eggs, and dead hatchlings show high levels of contamination with heavy metals, such as iron and arsenic. Green turtles also have elevated rates of tumors. It's not just the mining waste, said Cerri. The waters along the coast are also polluted by cellulose factories that operate in the Rio Doce rivershed. "These are the things that the turtles are facing now," he said.

At 8 p.m., I climbed into Cerri's Jeep. The night was black and starless, heavy clouds smothering the

cosmos. Looking for tracks is preferable to looking for turtles, Cerri told me, because one can easily mistake a rock or a piece of driftwood for an animal. After a short time driving along the beach, he spotted a familiar trail in the sand. In the red circle of light from his flashlight, I watched a giant loggerhead turtle scooting down a steep slope of sand. She had just laid a clutch of eggs and was returning to the ocean. Aside from Cerri's flashlight, the only light illuminating the scene rose from the froth of the ocean waves breaking

If you cannot drink the river water, if you cannot swim in the river, there's no way to relate to the river.

on the shore. That white light was the turtle's guide, Cerri told me. Finally, a wave came and washed her out to sea.

Cerri marked the nest so he could return later to build a protective fence around it. When the babies hatch, the biologists guide them to the ocean, but they make sure they feel the sand first, "so they can memorize the beach," he said. The turtles return to lay their eggs on the same shores where they are born. I was struck by the curious connections some creatures have to specific places, across generations. The rest of the turtles' lives are lived at sea, where they often traverse vast stretches of ocean with no landmarks in sight. How do they find their way?

Scientists have learned that the turtles rely in part on signals from the Earth's magnetic field. But the hatchlings also depend on the motions of the waves, which direct them into specific networks of currents that keep them safe and help them navigate. Without the cherished waves of Regencia, these turtles might not be able to cross the open ocean or know how to return to the beaches where they were born.

ON MY LAST DAY IN BRAZIL, I woke up early and headed down to the water, intending to give the wave another try. Along the beach lie several different surf breaks, each with different defining features. There is the fast, shallow tube by the turtle reserve at the far edge of town, known as Reserva, that I had already tried, and a long serpentine wave just south of the river mouth. A few other breaks lie in between. I saw some young surfers heading down the beach and followed them to the spot next to the river mouth.

The water was an opaque chocolate color and was peppered with debris, bits of black wood. But the shape of the wave was friendlier, the lip a little less steep. This time, the drop was manageable. I caught several waves in succession and rode them to the end. The rides were not long, but long enough that I could empty my mind of everything but the cadence of the water, the power of the ocean beneath my feet. I was thrilled to share with the other surfers this strange communion with something so fleeting and so infinite.

As I climbed back onto the beach, I was reminded that, at the smallest level, matter is both particle and wave, a fact that hints at a level of connectedness in the universe that is still difficult for most of us to comprehend. Perhaps the wave was telling me this: Every wave is many waves, nature is plural, so the efforts we take to protect it must be, too. The new law is not just about a surfer's wave. It's about a cherished river and the people who live on its banks. It's about turtles with ancient ties to these shores. And it's part of a much broader movement that is sustained by the idea of the interconnectedness of all life. But nature is also local and some of the most powerful conservation efforts are grounded in the direct connections individual people have to the places where they live. When we get close to nature, what we see is bounded by love: a sweet river, a single turtle ambling toward the sea, a beautiful wave. ☺

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Star Siblings Tell Tales of Galactic Chaos

Stellar bodies from other galaxies are all around us

BY PAUL M. SUTTER



S CATTERED ACROSS THE UNIVERSE are stars that shine subtle hints of a shared ancestry. They might be thousands of light-years apart, almost indistinguishable from other, nearer stars that surround them, but similarities—their ages, their compositions, and their orbits—reveal a common origin story. And astronomers can now use these stellar kin-groups to reconstruct the chaotic, often violent, history of galaxies.

Galaxies are the bustling cities of the universe, home to almost all its stars, and through their histories, we can learn about the grand forces that shape the organization of matter.

To trace these stellar genealogies, scientists look to the stars' conception. Stars are rarely born alone. Instead, a single massive cloud of gas and dust—called a giant molecular cloud—filled with a particular proportion of elements will spontaneously collapse and fragment, popping out tens, hundreds, and sometimes thousands of stars at once. The famous Orion Nebula, a delight to backyard astronomers, is one such active star-forming region.

But shortly after their birth, these stars begin to leave the nest. While initially tightly knit, they do not possess enough gravity to bind to each other. Any little disturbance—a passing neighbor nebula, gravitational interactions with each other—sends the stars farther away from each other on a path chosen through sheer random chance, like spilled salt scattering on the counter. In only a few million years, the stars, once birthed from the same gas cloud, can be tens of thousands of light-years apart, each one set to follow its own orbital trajectory around the galaxy.

It's in the details—a similar orbital origin point, a mutual age, a common abundance of heavy elements—that stars retain a blueprint of their birthplace. And scientists are now able to start charting these pasts.

By matching these properties to that of the sun, for example, in 2014 astronomers were able to find our own first-known stellar sibling. Located in the constellation Hercules and sitting 110 light-years away, the star, named HD 162826, can be seen with a small telescope. The discovery came as a surprise. Even though the sun





Shortly after their birth, stars begin to leave the nest.



likely has thousands of siblings, they were thought to be so far away by now as to elude confirmation of a match. But HD 162826 just happened to be close enough that the team could confirm its abundance of elements and reconstruct its orbital motion, indicating that four and a half billion years ago, that star and our sun likely shared a point of origin.

Essentially all stars belong to one such family group or another. If the group is young enough, such as the well known Pleiades cluster, then the identification is easy. There simply hasn't been enough time for the members to scatter away, and the stars still live in the same neighborhood. But most stars cannot be matched to their siblings; it takes extensive surveys covering millions, if not billions, of stars to tease out the signatures of a few kin groups. The vast majority of those identified groups are easily picked out as members of the Milky Way.

But among the 300-odd billion stellar denizens of the Milky Way, there are some groups that simply ... don't belong. They have an odd abundance of elements, or strange orbital properties. They don't share the genetic patterns of the bulk of our galaxy's stars.

Take, for example, the oddly named Gaia Sausage, discovered in 2018. The "Gaia" comes from the European Space Agency's Gaia spacecraft, which has amassed, so far, a catalog of more than 2 billion stars with detailed information on their properties. The "sausage" part is less obvious. When astronomers plot the circular motion versus the radial motion of stars in our galaxy, a large, elongated, sausage-like lump appears in the plot, made up of a collection of stars unlike the others in the Milky Way.

But these stars in the Gaia Sausage haven't remained clustered together. They are currently scattered all

around the Milky Way, their thin threads of commonality all that betrays their shared history. They have a common proportion of heavy elements, or "metallicity." And their orbits are extremely elliptical, bringing the stars brushing up against the core of the galaxy then flinging them back out more than 60,000 light-years away. In their commonality, they tell the story of a once-mighty galaxy eventually consumed and obliterated.

Cosmologists give this process an innocent-sounding name: hierarchical galaxy formation. But what that means is that our contemporary Milky Way, like all massive and proud galaxies in the universe, has lived a violent life, and only acquired its present-day bulk through devouring its neighbors.

Billions of years ago, there were no galaxies. In this period, some 100 million years after the Big Bang, there weren't even any stars. There was just a relatively smooth continuum of hydrogen, helium, and dark matter spread across the universe. But within that continuum, there were small density differences, places of slightly higher or lower density. Over time—hundreds of millions of years—those regions of higher density accreted more and more material, forming the gravitational seeds that would eventually grow up to become galaxies and form stars of like-histories. As smaller galaxies venture too close to large ones, their constituent stars get consumed and scattered within them.

We can only understand the details of galactic mergers through computer simulations that recreate these titanic events, tracing them through the shared lineages of these ancient, subsumed stars. Through these simulations, cosmologists see just how cataclysmic the process is.





In the case of a minor merger, when a large galaxy such as the Milky Way consumes a small one, the process might look something like this: The smaller galaxy feels a different gravitational pull at different locations, causing it to stretch out. It elongates, turning from a dense spherical clump to a long, thin stream. This stream then plunges headlong into the consuming galaxy, where its individual stars are then strewn about into random orbits.

After a few billion years, you would never know that anything had ever happened.

The only clues we have today are the common origin of those far-flung stars. But the Gaia Sausage is not the only dispersed ancestral group. There are other such strands of these hidden histories. The Sagittarius Stream, discovered in 2002 is a “ghost” remnant of the Sagittarius Dwarf Elliptical Galaxy. It consists of a thin strand of stars and gas ripped from its parent galaxy looping around the core of the Milky Way; we seem to have caught this merger event toward the end, but not yet at its final moments.

And there are more such streams: the Arcturus, the Helmi, the Palomar 5. There is even the Monoceros Ring, a community of stars that make three complete circles around the Milky Way. Each stream represents a distinct kinship, a shared heritage from a once-intact galaxy otherwise lost to history.

Some former galaxies were defeated and swallowed by the Milky Way so long ago that we can barely discern them. Hypothesized in 2020, the Kraken Galaxy is thought to have contributed roughly 10 percent of the Milky Way’s present-day collection of globular clusters—tight dense clumps of stars that retain their own shape. In this case, the remnant population of the Kraken resisted further obliteration.

These smaller galaxies consumed by the Milky Way also alter their host; they change the composition, structure, and chemical makeup of their new-found home. Another name for the Gaia Sausage is Gaia Enceladus, named after the mythological giant buried under Mount Etna and responsible for its earthquakes. For the Milky Way, the collision with Gaia Enceladus disrupted its prominent thin disk of stars, puffing it out and causing the formation of an ancillary, thicker disk.

Some ancient star cousins might even be in our neighborhood of the galaxy. Recently, a team of

In the details, stars retain a blueprint of their birthplace.

astronomers discovered 20 stars within a few thousand light-years of the sun that all might share a common ancestry. Given their particular makeup of heavy elements and the scattered nature of their orbits, the astronomers think that they are the leftovers of a truly ancient galaxy, named Loki, which merged with ours when the Milky Way was first coalescing in the darkness of the early universe, some 11-12 billion years ago.

But those who live by the sword, die by the sword—even galaxies. The Milky Way has merged, acquired, destroyed, and cannibalized countless neighbors, engulfing their surviving stars and matter within its vast bulk. But those conflicts were all unequal, against foes far smaller than our own galaxy.

Sitting 2.5 million light-years away is a true peer to the Milky Way, the Andromeda Galaxy, resplendent with more than 1 trillion stars, and roughly equal to our own galaxy in total mass. And it’s headed right for us. In about 5 billion years, our two galaxies will begin to merge together, a process that will take more than half a billion years to complete.

The new mega-galaxy will be unrecognizable. No spiral arms, no flat disk. Just an elliptical lump of stars mixed together in randomized orbits. Perhaps some future astronomer, living in an age well after our own sun has died, will scan their heavens and find a population of stars that share a common age and metallicity; a family born in the Milky Way but flung distantly through that reorganized cosmos, the faintest of patterns tying them back to a vanished homeland. ☺

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Meet My Pal, the Ancient Philosopher

How friendship with long-dead thinkers can help us live better

BY HELEN DE CRUZ

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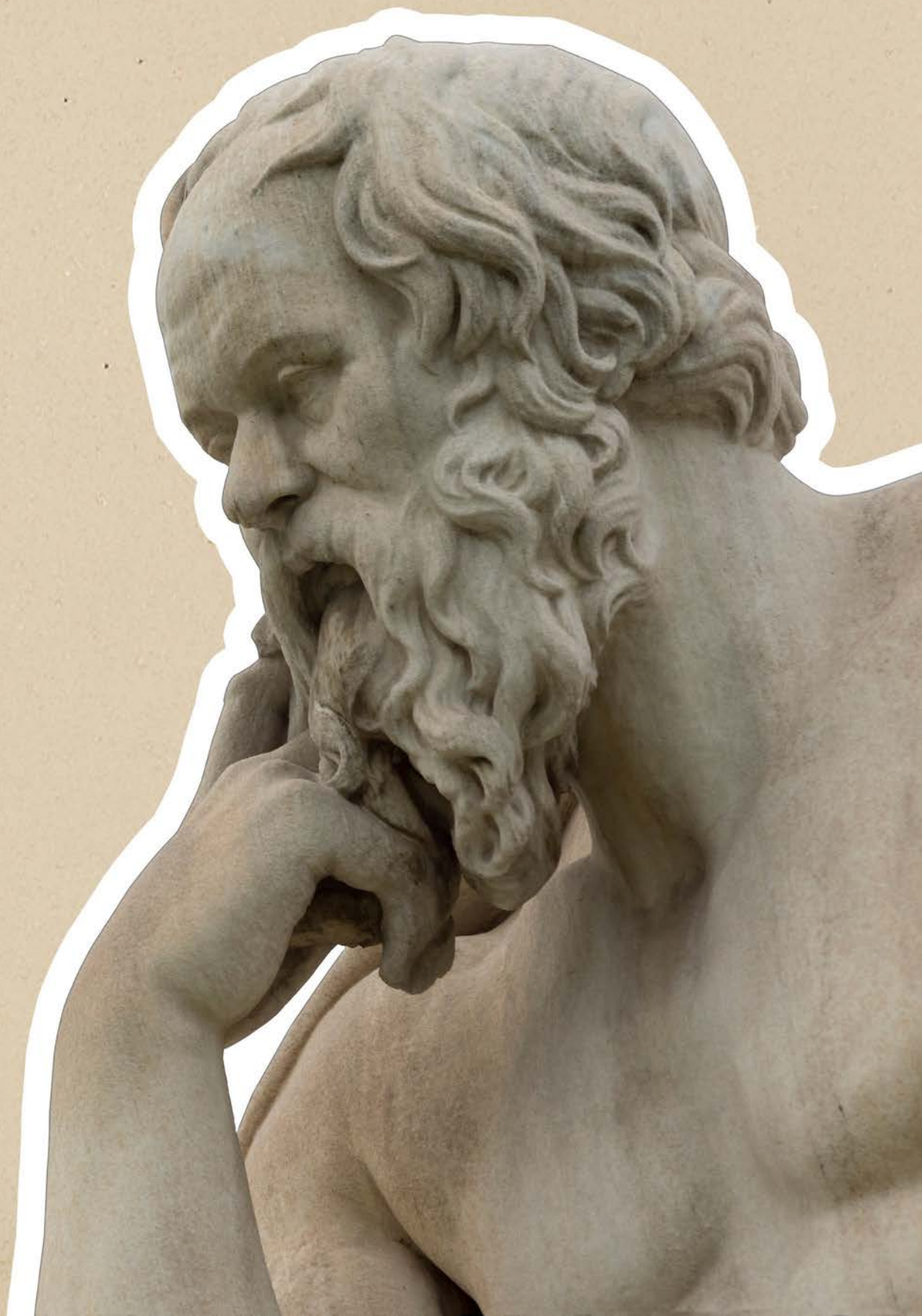
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TO DO PHILOSOPHY, you don't need expensive labs or equipment. You don't need a huge team. You can do it all by yourself. The downside is that philosophers are often lonely. Reading in solitude while wrestling with your own thoughts is difficult. We do discuss and debate our ideas with others at conferences and symposia, but these peers, invaluable as they are, are bounded by many of the same constraints we are, living and thinking in our own brief historical moment. To overcome this myopathy of the mind, I stumbled upon an unexpected hack: not just reading the ancients, but becoming friends with them.

The medieval Japanese Buddhist philosopher Kenkō described this practice as follows in his free-flowing brush style: “The pleasantest of all diversions is to sit alone under the lamp, a book spread out before you, and to make friends with people of a distant past you have never known.” The medieval Italian poet and philosopher Petrarch not only wrote letters to his living friends, but also to the dead, such as Cicero, who lived 1,400 years before. In her biography of Rahel Varnhagen, an 18th-century German writer and salon host, Hannah Arendt called her “my closest friend, though she has been dead for some hundred years.”

Once you spot these friendships with the ancients, you start to see them everywhere (I wrote more about them recently in the *Journal of the American Philosophical Association*). What do philosophers get out of not merely reading old philosophy texts but also befriending their authors? How does one even do this, given that the other person is, well, dead?

About 10 years ago, I was unaware of this practice, and I could not foresee how it would transform the way I think. I was a proper academic philosopher, writing in the style and developing the kinds of arguments that were suited for mainstream philosophy journals—for example, on whether the evolutionary origins of moral or mathematical beliefs cast doubt on these beliefs. My citations to old philosophical texts were few and sparing. I used them mainly to support my arguments. I wondered whether people like Plato or Nāgārjuna could help me at all, given that their cultural contexts (ancient Greece and ancient India, respectively) were so different.

This changed when I read the *Mengzi*, a Chinese philosophy book from the Warring States Period (around the fourth century B.C.) about ethics, etiquette, and politics, with sayings and dialogues attributed to the philosopher Mengzi (also Latinized as Mencius). I read this book because I wanted to diversify my syllabus and to introduce some Chinese philosophy in my ethics class at Oxford Brookes University (where I was a senior lecturer at the time). I wasn't prepared for how much this work would blow me away. Maybe I was under the influence of stereotypes of Chinese philosophy as collections of ambiguous sayings by sage old men with wispy beards. Instead, I found a deeply challenging picture of humanity.

MENGZI OFFERS THE THOUGHT EXPERIMENT of a child who is about to fall in a well. He writes that anyone would be alarmed at the sight, not because of ulterior motives—such as praise from the parents if one were to help the child—but because of genuine altruistic motives. Mengzi held that we all have within us emotional beginnings (or “sprouts” as he calls them) of virtue. For example, the emotion of compassion is the sprout of the virtue of benevolence. We are all born with these sprouts the way we are born with four limbs. To become a good person, one must nurture the sprouts the way one nurtures young plants.

I fell in love with Mengzi, particularly because it was the first ethics text I read that gave me helpful advice to cultivate my own virtues. Mengzi tells you that you have all the resources to be a good person within you. You don't need to abide by ethical systems

dreamt up by others, the sprouts of goodness are already there. From that starting point, it's just slow and gradual practice. For example, if I lost my temper yesterday, I have an opportunity not to do so today. If my comments on the work of a student have been too harsh, I can tell them that there were also many good things in the work and be gentler with students next time.

Up until that point, I saw philosophical papers as 9,000-word sized self-contained publishable units where you cite philosophers to support your arguments, or to engage with their arguments to critique them. But I didn't truly love any philosophical text, not the way I can love a piece of music, a novel, or a painting. That changed with Mengzi. Mengzi transformed not only my view on human nature, but also how I engage with philosophical texts. He says that if you cannot find suitable friends among the living, then you should "ascend to examine the ancients. Recite their Odes and read their Documents. But can you do this without understanding what sort of people they were? Because of this, you must examine their era. This is how friendship ascends."

What Mengzi says here is that to befriend ancient philosophers, we must immerse ourselves not only in their words but also attempt to do the same with the cultural context in which they lived and worked. That understanding is not one of an impartial scholar but of a friend. A friend knows where you are coming from and realizes why you hold certain views.

I TRIED THIS PRACTICE by talking to Mengzi in my mind. In my imagination, he looks more like a young C-drama actor than like the severe scholar who is featured in *Half Portraits of the Great Sage and Virtuous Men of Old*.

I asked him questions and requested his help in the interpretation of some of the more difficult passages in the *Mengzi*. This prompted me to read more about his era, the Warring States Period, when smaller states were invaded by larger ones. I interrogated the philosopher, and sometimes, in my mind, he answered back.

I interrogated the philosopher, and sometimes, in my mind, he answered back.

For example, I found him helpful when considering a tricky professional situation some years ago in which I was being urged to not give an invited talk because the organizer had made some remarks that sounded, as reported, transphobic. If I accepted and gave the talk, I would implicitly condone him. On the other hand, if I didn't give the talk, I would cave to peer pressure without knowing all the details. What does Mengzi recom-

mend? To give the presentation, I would be in line with the virtue of ritual, as it is awkward etiquette to decline a talk you have accepted earlier. However, I might be hurting the people who were upset or harmed by the remarks, which would not be in line with the virtue of benevolence.

For Mengzi, situations like these require the virtue of wisdom. Wisdom is a kind of meta-virtue that requires that you weigh the dilemma carefully. In this case, I contacted people involved in the situation to learn more about it, and we reached a compromise that was acceptable to all, namely that I would give short remarks at the start of my presentation about how the state of trans philosophers in our profession could improve. This was also in line with the fourth Mengzian virtue, righteousness, where you try to use whatever platform you have to further the common good.

The great thing about Mengzi's views on virtue is that you can mess up; it doesn't mean you are a terrible human being. You can always try again. For example, if you have been an ungracious partner, you can try to be more gracious tomorrow. Unlike Scrooge in *A Christmas Carol* who can only get shocked into becoming a better person by ghosts and visions, it is possible to do so gradually, in the small observations and practices of everyday life. While you cannot undo past harms, it is never too late to prevent yourself from causing future ones.

If you ask Westerners whether we can improve by practice in such endeavors as playing the guitar, or tennis, or even writing, they will say, "of course!" But if you ask them if we can improve our virtue in this way, many will say no: Some people are simply born more virtuous



OLD FREIND I picture my friend Mengzi more as a young actor than the severe scholar he is depicted as in *Half Portraits of the Great Sage and Virtuous Men of Old*.

than others or are otherwise made more virtuous by circumstances largely out of their control. But Mengzi thinks that you can practice your virtue by growing your sprouts. He likens cultivating your virtue with playing the board game Go. “Now, Go is an insignificant craft. But if one does not focus one’s heart and apply one’s intention, then one won’t get it.”

WHEN YOU MAKE FRIENDS with a long-dead philosopher, you don’t think of them in a detached, objective manner. That is, we better understand where they are coming from, and why they hold certain views. Though this doesn’t mean we let them off the hook.

In a June 1345 letter to his dead friend the Roman philosopher Cicero, Petrarch laments Cicero’s

I didn’t truly love any philosophical text, not the way I love a piece of music, a novel, or a painting.

shortcomings, particularly his inability to live up to his own standards: “What good is there in teaching others, what benefit is there in speaking constantly with the most magnificent words about the virtues, if at the same time you do not give heed to your own words?” We can share our candid thoughts with our good friends.

Befriending a long-dead philosopher also helps us to understand ourselves better. It is an easy reflex to “cancel” any dead philosopher—write them and all of their work off part and parcel—because of some unsavory (racist, sexist, classist, etc.) views they held. It is more difficult to engage with their work, to understand it, while also recognizing that these views are elements of their work. This helps us to see ourselves as thinkers who may hold some flawed views, but who do this in a larger picture of humanity striving to better understand ourselves and the world in which we live. We are not so different from the ancients, and the problems they dealt with are similar to ours.

For example, many of us are forced, or greatly pressured by circumstances, to work for companies solely focused on profit, that are short-sighted, and even corrupt. Ancient friends such as Confucius and Mengzi considered this as an important dilemma: It is vital to know when to step away.

With the climate spinning out of control, the fallout of a pandemic (and likely others in the making), and the rise of authoritarianism, I cannot help but feel doubts about Mengzi’s core view that human nature is good. By this, Mengzi did not mean that each individual human being is good. But he did believe that we are good by nature, the way it is in the nature of a duck to swim. Due to circumstances (for example, living

in captivity without nearby water), a duck may never swim. Similarly, circumstances can make a nation's actions devoid of virtue. But the nature of the people in those nations is to be good. What does this mean?

To better grasp this idea, I examined Mengzi's era. His time, the Warring States Period, was one of unrest, epidemics, and violent conflict. He was an advisor to the ruler of Qi, helping to shape policy and foreign affairs. Yan, a neighboring smaller state, was weakened due to a succession crisis. The ruler of Qi asked if it was morally permissible to annex Yan (this was a common policy during the period). Mengzi advised that it was. However, he was horrified by how Qi's ruler took the state, by looting and by killing huge numbers of innocent civilians. Mengzi resigned in disgust, even though he was unable to obtain another position. He was well aware of the depths to which humans can plunge, and yet, in spite of this, he still held that human nature is good.

A possible way to read this is to see his view of human goodness as aspirational. Having faith in the goodness of humanity is, as Martin Luther King, Jr. and other activists have demonstrated, an attitude that can help you to make the needle move in the right direction. Mengzi lived in desperate times. We, like Mengzi's peers, may fervently wish to live in a more peaceful era. "So do all who live to see such times," as Gandalf advises Frodo in *Lord of the Rings*, "but that is not for them to decide. All we have to decide is what to do with the time that is given to us." This is what Mengzi did, and his view of human nature was crucial to this.

He arguably believed that it is part of human nature to aspire to be good. In one passage from the *Mengzi*, for example, a ruler asks the philosopher if he should be a king who rules by virtue, that is, by showing a good example and being benevolent, or rather if he should be content by ruling as a hegemon who uses *realpolitik*—using purely instrumental political means, even if not always above the board, much as Machiavelli prescribes—to achieve one's goals. The ruler is worried that he isn't good enough to be a virtuous king. "Can one such as ourselves care for the people?" he asks. Mengzi says simply, "You can." He thinks the king is able to do this, because he showed compassion on earlier occasions, such as when he spared an ox that was led to be ritually slaughtered.

If you cannot find suitable friends among the living, you should "ascend to examine the ancients."

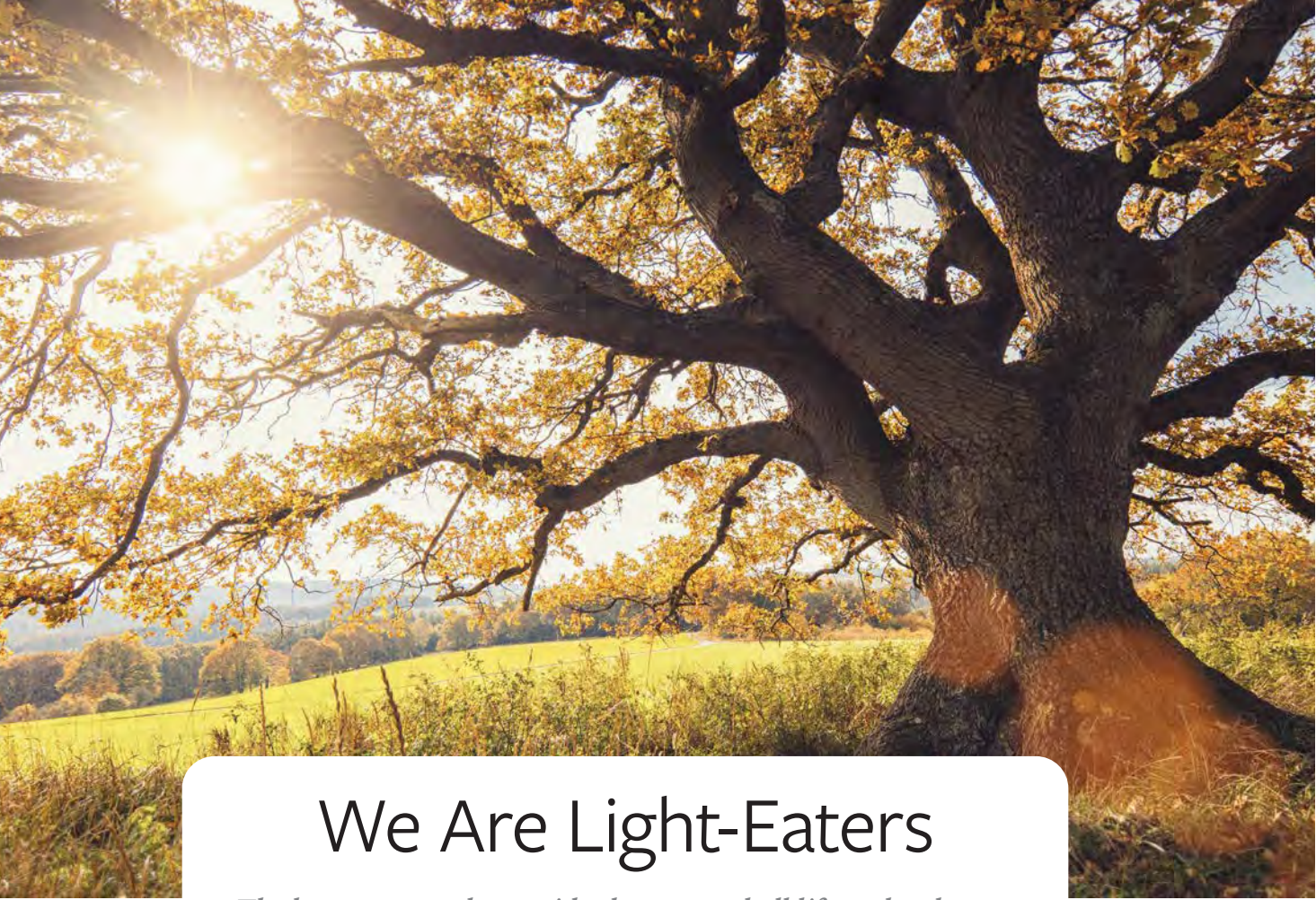
If he can feel compassion for an animal, he should all the more be capable of empathizing with his subjects, who are human beings.

In another passage, Mengzi mentions the village worthies, the prominent people in the village everyone respects. Mengzi, by contrast, holds them in low esteem. When he is asked why he, like Kongzi (Confucius), views them with disdain, he replies that the village worthies settle for mediocrity: "Born in this era, we should be for this era. To be good is enough." Mengzi thinks that with this mindset, the village worthies set the bar too low for themselves. They think that if you live in a time when the standards are low, it's okay to do the bare minimum to be deemed virtuous.

What my conversations with my ancient friend Mengzi helped me to understand is that the norms and ideas about what being a good person is, and what a good life is, are not restricted to our time. We can be ambitious in what we hope and strive for, by reaching out to the ancients who continue to inspire us. This way, we can overcome the limitations of being born in our own era and can situate ourselves in a much bigger world, brimming with possibilities and with many voices of the past and present to guide us. ☺

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We Are Light-Eaters

The language we share with plants—and all life under the sun

BY HOLLY HAWORTH

AT THE PARK NEAR MY HOME in Georgia grows a towering oak tree I often visit at the end of the day, when I feel weary. When I reach it, I run my hands over its rough gray fissured bark. I walk a circle around it, imagining its roots winding through the earth below. It is magnificent, this oak tree, and nothing at all like me. Its bark is utterly strange against my own skin. Its roots that hold steadfast in the soil are not like my wandering, restless feet. I tilt my head back to take in its vaulted, spacious canopy, its long curving limbs. Up there, with its thousand spreading leaves, the tree performs a feat I could never hope to accomplish.

R. CLASSEN / SHUTTERSTOCK

While I must eat plants, or, sometimes, other plant-eating animals, to obtain the energy I need, the tree can eat the light of the sun. Far above me, the chloroplasts in each leaf's cells capture photons from our nearest star. With the help of carbon dioxide inhaled through tiny respiratory passages in the leaves called stomata, and the water that circulates through the leaves' veins, the tree turns the sunlight into glucose and so keeps growing year after year, sending its roots deeper and unfurling more leaves.

My eyes move along the limbs that loft themselves skyward, reaching toward the light. As I gaze into the shimmering green and feel my face and arms warmed by the evening sun, I sense that I too am nourished by this golden light. The cells in my body tell a primordial story of my kinship with this alchemist tree. In fact, I wonder if it's correct to say that I don't eat light. Don't we humans have our own ways, too?

As sunlight infuses the cells of our largest organ, the skin, we synthesize the Vitamin D that is crucial for absorbing the minerals that build our bones, among many other metabolic functions. (Despite its name, Vitamin D is not a vitamin but a hormone produced in response to sun exposure.) As sunlight enters our eyes, our rods and cones receive the incoming photons and translate the bright world around us into images—or the dim world, as rods respond to even a single photon.

It was once thought that rods and cones were the only photoreceptive cells in our eyes. But at the turn of the millennium, researchers identified a different type of cell in the retina whose existence had been suspected since 1923, when geneticist Clyde Keeler noticed that the pupils of blind mice still dilated when exposed to light. These cells—named intrinsically photoreceptive retinal ganglion cells—have nothing to do with the formation of images.

Instead they send signals to an area deep in the center of the brain called the hypothalamus. Inside the hypothalamus is the suprachiasmatic nucleus, better known as the circadian clock. A tiny region that contains about 20,000 neurons (compared to the visual cortex that contains 5 billion), this “clock” is central to our lives. Like a conductor counting out measures, it orchestrates a symphony of precisely timed physiological processes, from circulating hormones to maintaining body temperature to synthesizing proteins to regulating sleep and the rhythms of our heartbeat.

The circadian clock, having evolved under regular 24-hour cycles of light and darkness for millions of years, is now so deeply rooted in our biology that it is considered internal, persisting even in the absence of external cues. The same is true for plants, which evolved circadian rhythms independently of, and long before, us animals. Even when kept in darkness, some plants will still raise their leaves each day and lower them at night as if to sleep.

Light
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But even as the clock ticks internally, from moment to moment it also receives signals from the sun. The sun is our most powerful *zeitgeber*, as chronobiologists call it, meaning “time-giver” in German. Just as the clock on my grandmother’s mantle had to be wound with a key each day as it began to run down, so our internal clocks are kept running at the appropriate speed by daily exposure to light and darkness in a process called photo-entrainment. Even with our eyes closed, the photosensitive cells in our retinas register light or darkness, continually attuning our ancient internal clock to our present environment. As we know by the experience of jet lag as we travel across time zones, we can feel like a broken clock when our bodies fall out of entrainment with the sun.

One of the best-studied light-induced oscillations in the body is the release of melatonin, a hormone that acts like a cellular lullaby, signaling our bodies to sleep with the onset of darkness. It does not just send us floating along a river of dreams, though. As melatonin surges in the absence of light, it also sweeps unstable molecules called free radicals from the mitochondria that power our cells, acting as a powerful antioxidant. Just as important as eating light, then, is fasting from it.

The same photosensitive cells that wake us at dawn are the ones that disturb our sleep when a streetlight shines through the curtains at midnight. Exposure to light after dark suppresses melatonin release and delays the sleep phase of the circadian rhythm. Since the advent of electricity, it has become easy to make the proverbial sun blaze all night or to interrupt the night with flashes of day, to prolong sundown or rush the sunrise by burning fossil fuels—buried and compressed plants that ate the sunlight millions of years ago. Bathed in the glow of the false suns that our lightbulbs and digital screens are, our eyes send messages to our master clock that

cause confusion. By eating light at the wrong times we disrupt our sleep, metabolism, energy, mood, and hormonal cycles.¹ There is even evidence that links circadian rhythm disruption to higher risks of cancer.²

Since the discovery of the circadian clock in the hypothalamus, scientists have found similar clocks in several other areas of the brain. Some of these regions are responsible for mood and cognition. This means that the false suns whose light we eat in irregular patterns can directly cause disorders such as depression and anxiety, as well as difficulties performing cognitive tasks and learning, independent of sleep disruptions.

Such clocks, it turns out, have also been found in peripheral tissues in the lungs, skeletal muscles, liver, and heart, all of them exhibiting a rhythmicity governed by light. Even the eyes, apart from the retinal ganglion cells that receive light, contain these clocks. In fact, when single cells are isolated from their tissues, most of them demonstrate such rhythms. Our cells, in multitude, each entraining to the photons our eyes receive, coordinate the biochemical processes of our organs within the 24-hour cycle.

Clocks have been discovered in the brains, tissues, or cells of organisms in every branch of the phylogenetic tree, from plants and mammals to insects, algae, fungi, and even single-celled bacteria. While the first clocks likely evolved 2.5 billion years ago in oceanic cyanobacteria, circadian rhythms appear to have evolved independently in each limb of life's tree, each growing toward the same source.³

Now, the light of our false suns, which have grown ever brighter and more numerous, disturbs even the rhythms of trees, inducing them to leaf and bud and flower too soon, making them more susceptible to pathogens and frost damage and causing them to miss their ancient annual appointments with specific pollinators.⁴

When I visit the oak tree as the days get shorter in the autumn, I watch in wonder as its canopy flushes scarlet. It is cutting off the flow of chlorophyll, entraining to seasonal changes as the Earth circles the sun and the duration and intensity of light fluctuates. I pick up a leaf from the ground at my feet and remember that my body is entraining, too. I will produce more melatonin and less Vitamin D with less sun exposure through the winter months.

Though the tree seems so radically different than me, so strange at times, I remember that we travel together in this spinning dance around our star, the sun that makes life possible and orchestrates the rhythm of our days and seasons, that gives us a pulse. Twirling the leaf, with its stem between my thumb and index finger, I feel my aeons-long cellular kinship with all light-eaters. All beings under the sun. ☺

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AI Is the Black Mirror

Why the kinship between artificial intelligence and the human mind is terrifying

BY PHILIP BALL



PHILOSOPHER SHANNON VALLOR and I are in the British Library in London, home to 170 million items—books, recordings, newspapers, manuscripts, maps. In other words, we’re talking in the kind of place where today’s artificial intelligence chatbots like ChatGPT come to feed.

Sitting on the library’s café balcony, we are literally in the shadow of the Crick Institute, the biomedical research hub where the innermost mechanisms of the human body are studied. If we were to throw a stone from here across St. Pancras railway station, we might hit the London headquarters of Google, the company for which Vallor worked as an AI ethicist before moving to Scotland to head the Center for Technomoral Futures at the University of Edinburgh.

Here, wedged between the mysteries of the human, the embedded cognitive riches of human language, and the brash swagger of commercial AI, Vallor is helping me make sense of it all. Will AI solve all our problems, or will it make us obsolete, perhaps to the point of extinction? Both possibilities have engendered hyperventilating headlines. Vallor has little time for either.

She acknowledges the tremendous potential of AI to be both beneficial and destructive, but she thinks the real danger lies elsewhere. As she explains in her 2024 book *The AI Mirror*, both the starry-eyed notion that AI thinks like us and the paranoid fantasy that it will manifest as a malevolent dictator, assert a fictitious kinship with humans at the cost of creating a naïve and toxic view of how our own minds work. It's a view that could encourage us to relinquish our agency and forego our wisdom in deference to the machines.

Reading *The AI Mirror* I was struck by Vallor's determination to probe more deeply than the usual litany of concerns about AI: privacy, misinformation, and so forth. Her book is really a discourse on the relation of human and machine, raising the alarm on how the tech industry propagates a debased version of what we are, one that reimagines the human in the guise of a soft, wet computer.

If that sounds dour, Vallor most certainly isn't. She wears lightly the deep insight gained from seeing the industry from the inside, coupled to a grounding in the philosophy of science and technology. She is no crusader against the commerce of AI, speaking warmly of her time at Google while laughing at some of the absurdities of Silicon Valley. But the moral and intellectual clarity and integrity she brings to the issues could hardly offer a greater contrast to the superficial, callow swagger typical of the proverbial tech bros.

"We're at a moment in history when we need to rebuild our confidence in the capabilities of humans to reason wisely, to make collective decisions," Vallor tells me. "We're not going to deal with the climate emergency or the fracturing of the foundations of democracy unless we can reassert a confidence in human thinking and judgment. And everything in the AI world is working against that."

AI AS A MIRROR

To understand AI algorithms, Vallor argues we should not regard them as minds. "We've been trained over a century by science fiction and cultural visions of AI to expect that when it arrives, it's going to be a machine mind," she tells me. "But what we have is something quite different in nature, structure, and function."

Rather, we should imagine AI as a mirror, which doesn't duplicate the thing it reflects. "When you go into the bathroom to brush your teeth, you know there isn't a second face looking back at you," Vallor says. "That's just a reflection of a face, and it has very different properties. It doesn't have warmth; it doesn't have depth." Similarly, a reflection of a mind is not a mind. AI chatbots and image generators based on large language models are mere mirrors of human performance. "With ChatGPT, the output you see is a reflection of human intelligence, our creative preferences, our coding expertise, our voices—whatever we put in."

Even experts, Vallor says, get fooled inside this hall of mirrors. Geoffrey Hinton, the computer scientist who shared this year's Nobel Prize in physics for his pioneering work in developing the deep-learning techniques that made LLMs possible, at an AI conference in 2024 that "we understand language in much the same way as these large language models."

It's easy to assert kinship between machines and humans when humans are seen as mindless machines.

Hinton is convinced these forms of AI don't just blindly regurgitate text in patterns that seem meaningful to us; they develop some sense of the meaning of words and concepts themselves. An LLM is trained by allowing it to adjust the connections in its neural network until it reliably gives good answers, a process that Hinton compared to "parenting for a supernaturally precocious child." But because AI can "know" vastly more than we can, and "thinks" much faster, Hinton concludes that it might ultimately supplant us: "It's quite conceivable that humanity is just a passing phase in the evolution of intelligence," he said at a 2023 MIT Technology Review conference.

"Hinton is so far out over his skis when he starts talking about knowledge and experience," Vallor says. "We know that the brain and a machine-learning model are only superficially analogous in their structure and function. In terms of what's happening at the physical level, there's a gulf of difference that we have every reason to think makes a difference." There's no real kinship at all.

I agree that apocalyptic claims have been given far too much airtime, I say to Vallor. But some researchers say LLMs are getting more "cognitive": OpenAI's latest chatbot, model o1, is said to work via a series of chain-of-reason steps (even though the company won't disclose them, so we can't know if they resemble human reasoning). And AI surely does have features that can be considered aspects of mind, such as memory and learning. Computer scientist Melanie Mitchell and complexity theorist David Krakauer have proposed that, while we shouldn't regard these systems as minds like ours, they might be considered minds of a quite different, unfamiliar variety.

"I'm quite skeptical about that approach. It might be appropriate in the future, and I'm not opposed in principle to the idea that we might build machine minds. I just don't think that's what we're doing right now."

Vallor's resistance to the idea of AI as a mind stems from her background in philosophy, where mindedness tends to be rooted in experience: precisely what today's AI does not have. As a result, she says, it isn't appropriate to speak of these machines as thinking.

Her view collides with the 1950 paper by British mathematician and computer pioneer Alan Turing, "Computing Machinery and Intelligence," often regarded as the conceptual foundation of AI. Turing asked the question: "Can machines think?"—only to replace it with what he considered to be a better question, which was whether we might develop machines that could give responses to questions we'd be unable to distinguish from those of humans. This was Turing's "Imitation Game," now commonly known as the Turing test.

But imitation is all it is, Vallor says. "For me, thinking is a specific and rather unique set of experiences we have. Thinking without experience is like water without the hydrogen—you've taken something out that loses its identity."

Reasoning requires concepts, Vallor says, and LLMs don't truly develop those. "Whatever we're calling concepts in an LLM are actually something different. It's a statistical mapping of associations in a high-dimensional mathematical vector space. Through this representation, the model can get a line of sight to the solution that is more efficient than a random search. But that's not how we think."



THE AI ETHICIST Shannon Vallor is raising the alarm on how the tech industry propagates a debased version of humans. If that sounds dour, Vallor certainly isn't. She wears lightly the deep insight gained from seeing the industry from the inside, coupled to a grounding in the philosophy of science.

They are, however, very good at pretending to reason. “We can ask the model, ‘How did you come to that conclusion?’ and it just bullshits a whole chain of thought that, if you press on it, will collapse into nonsense very quickly. That tells you that it wasn’t a train of thought that the machine followed and is committed to. It’s just another probabilistic distribution of reason-like shapes that are appropriately matched with the output that it generated. It’s entirely post hoc.”

AGAINST THE HUMAN MACHINE

The pitfall of insisting on a fictitious kinship between the human mind and the machine can be discerned since the earliest days of AI in the 1950s. And here’s what worries me most about it, I tell Vallor. It’s not so much because the capabilities of the AI systems are being overestimated in the comparison, but because the way the human brain works is being so diminished by it.

“That’s my biggest concern,” she agrees. Every time she gives a talk pointing out that AI algorithms are not really minds, Vallor says, “I’ll have someone in the

audience come up to me and say, ‘Well, you’re right but only because at the end of the day our minds aren’t doing these things either—we’re not really rational, we’re not really responsible for what we believe, we’re just predictive machines spitting out the words that people expect, we’re just matching patterns, we’re just doing what an LLM is doing.’”

Hinton has suggested an LLM can have feelings. “Maybe not exactly as we do but in a slightly different sense,” Vallor says. “And then you realize he’s only done that by stripping the concept of emotion from anything that is humanly experienced and turning it into a behaviorist reaction. It’s taking the most reductive 20th-century theories of the human mind as baseline truth. From there it becomes very easy to assert kinship between machines and humans because you’ve already turned the human into a mindless machine.”

It’s with the much-vaunted notion of artificial general intelligence (AGI) that these problems start to become acute. AGI is often defined as a machine intelligence that can perform any intelligent function that humans can,

Silicon Valley culture has the features of religion. It's unshakeable by counterevidence or argument.

but better. Some believe we are already on that threshold. Except that, to make such claims, we must redefine human intelligence as a subset of what we do.

"Yes, and that's a very deliberate strategy to draw attention away from the fact that we haven't made AGI and we're nowhere near it," Vallor says.

Originally, AGI meant something that misses nothing of what a human mind could do—something about which we'd have no doubt that it is thinking and understanding the world. But in *The AI Mirror*, Vallor explains that experts such as Hinton and Sam Altman, CEO of OpenAI, the company that created ChatGPT, now define AGI as a system that is equal to or better than humans at calculation, prediction, modeling, production, and problem-solving.

"In effect," Vallor says, Altman "moved the goalposts and said that what we mean by AGI is a machine that can in effect do all of the economically valuable tasks that humans do." It's a common view in the community. Mustafa Suleyman, CEO of Microsoft AI, has written the ultimate objective of AI is to "distill the essence of what makes us humans so productive and capable into software, into an algorithm," which he considers equivalent to being able to "replicate the very thing that makes us unique as a species, our intelligence."

When she saw Altman's reframing of AGI, Vallor says, "I had to shut the laptop and stare into space for half an hour. Now all we have for the target of AGI is something that your boss can replace you with. It can be as mindless as a toaster, as long as it can do your work. And that's what LLMs are—they are mindless toasters that do a lot of cognitive labor without thinking."

I probe this point with Vallor. After all, having AIs that can beat us at chess is one thing—but now we have algorithms that write convincing prose, have engaging chats, make music that fools some into thinking it was made by humans. Sure, these systems can be rather limited and bland—but aren't they encroaching ever more on tasks we might view as uniquely human?

"That's where the mirror metaphor becomes helpful," she says. "A mirror image can dance. A good enough mirror can show you the aspects of yourself that are deeply human, but not the inner experience of them—just the performance." With AI art, she adds, "The important thing is to realize there's nothing on the other side participating in this communication."

What confuses us is we can feel emotions in response to an AI-generated "work of art." But this isn't surprising because the machine is reflecting back permutations of the patterns that humans have made: Chopin-like music, Shakespeare-like prose. And the emotional response isn't somehow encoded in the stimulus but is constructed in our own minds: Engagement with art is far less passive than we tend to imagine.

But it's not just about art. "We are meaning-makers and meaning-inventors, and that's partly what gives us our personal, creative, political freedoms," Vallor says. "We're not locked into the patterns we've ingested but can rearrange them in new shapes. We do that when we assert new moral claims in the world. But these machines just recirculate the same patterns and shapes with slight statistical variations. They do not have the capacity to make meaning. That's fundamentally the gulf that prevents us being justified in claiming real kinship with them."

People really think the sun is setting on human decision-making. That's terrifying to me.

THE PROBLEM OF SILICON VALLEY

I ask Vallor whether some of these misconceptions and misdirection about AI are rooted in the nature of the tech community itself—in its narrowness of training and culture, its lack of diversity.

She sighs. “Having lived in the San Francisco Bay Area for most of my life and having worked in tech, I can tell you the influence of that culture is profound, and it’s not just a particular cultural outlook, it has features of a religion. There are certain commitments in that way of thinking that are unshakeable by any kind of counterevidence or argument.” In fact, providing counterevidence just gets you excluded from the conversation, Vallor says. “It’s a very narrow conception of what intelligence is, driven by a very narrow profile of values where efficiency and a kind of winner-takes-all domination are the highest values of any intelligent creature to pursue.”

But this efficiency, Vallor continues, “is never defined with any reference to any higher value, which always slays me. Because I could be the most efficient at burning down every house on the planet, and no one would say, ‘Yay Shannon, you are the most efficient pyromaniac we have ever seen! Good on you!’”

In Silicon Valley, efficiency is an end in itself. “It’s about achieving a situation where the problem is solved and there’s no more friction, no more ambiguity, nothing left unsaid or undone, you’ve dominated the problem and it’s gone and all there is left is your perfect shining solution. It is this ideology of intelligence as a thing that wants to remove the business of thinking.”

Vallor tells me she once tried to explain to an AGI leader that there’s no mathematical solution to the problem of justice. “I told him the nature of justice is we have conflicting values and interests that cannot be made commensurable on a single scale, and that the work of human deliberation and negotiation and appeal is essential. And he told me, ‘I think that just means you’re bad at math.’ What do you say to that? It becomes two worldviews that don’t intersect. You’re speaking to two very different conceptions of reality.”

THE REAL DANGER

Vallor doesn’t underestimate the threats that ever-more powerful AI presents to our societies, from our privacy to misinformation and political stability. But her real worry right now is what AI is doing to our notion of ourselves.

“I think AI is posing a fairly imminent threat to the existential significance of human life,” Vallor says. “Through its automation of our thinking practices, and through the narrative that’s being created around it, AI is undermining our sense of ourselves as responsible and free intelligences in the world. You can find that in authoritarian rhetoric that wishes to justify the deprivation of humans to govern themselves. That story has had new life breathed into it by AI.”

Worse, she says, this narrative is presented as an objective, neutral, politically detached story: It’s just science. “You get these people who really think that the time of human agency has ended, the sun is setting on human decision-making—and that that’s a good thing and is simply scientific fact. That’s terrifying to me.

We're told that what's next is that AGI is going to build something better. And I do think you have very cynical people who believe this is true and are taking a kind of religious comfort in the belief that they are shepherding into existence our machine successors."

Vallor doesn't want AI to come to a halt. She says it really could help to solve some of the serious problems we face. "There are still huge applications of AI in medicine, in the energy sector, in agriculture. I want it to continue to advance in ways that are wisely selected and steered and governed."

That's why a backlash against it, however understandable, could be a problem in the long run. "I see lots of people turning against AI," Vallor says. "It's becoming a powerful hatred in many creative circles. Those communities were much more balanced in their attitudes about three years ago, when LLMs and image models started coming out. There were a lot of people saying, 'This is kind of cool.' But the approach by the AI industry to the rights and agency of creators has been so exploitative that you now see creatives saying, 'Fuck AI and everyone attached to it, don't let it anywhere near our creative work.' I worry about this reactive attitude to the most harmful forms of AI spreading to a general distrust of it as a path to solving any kind of problem."

While Vallor still wants to promote AI, "I find myself very often in the camp of the people who are turning angrily against it for reasons that are entirely legitimate," she says. That divide, she admits, becomes part of an "artificial separation people often cling to between humanity and technology." Such a distinction, she says, "is potentially quite damaging, because technology is fundamental to our identity. We've been technological creatures since before we were *Homo sapiens*. Tools have been instruments of our liberation, of creation, of better ways of caring for one another and other life on this planet, and I don't want to let that go, to enforce this artificial divide of humanity versus the machines. Technology at its core can be as humane an activity as anything can be. We've just lost that connection." 🌀

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





The Once and Future Woods

Cathedrals, seed banks, and oaks: How to live in times of change

BY VERONIQUE GREENWOOD





IN A BRIGHT FALL day in England, near the town of Peterborough, I make my way to a postage stamp of forest on the edge of a regional highway. All around are plowed fields, some with corn still standing.

But I, with the A47 highway's traffic humming some 300 feet off, am standing next to a 500-acre patch of ancient woodland. In England, this is a designation for places that have been wooded continuously since at least 1600, when records begin to be available. This doesn't mean that the trees themselves—the oak, the ash, the hazel—are old. They may be fairly young, because woodlands have a long tradition of human use: The trees in the Bedford Purlieu Wood have been cut and regrown many times in the course of its existence. What remains intact, however, is the diversity of species. In the undergrowth and the soil, a phenomenally rich stew of plant and other life lives. And I am here today because the bleeding edge of biodiversity conservation has just arrived in a little white hatchback.

Isabel Negri and Matthew Jeffery climb out. They are employees of the Royal Botanic Gardens, Kew, where the Millennium Seed Bank harbors the world's largest collection of wild plant seeds. Woodland trees are dying at an incredible clip, under siege from disease and changing climate. So they are here, with their clipboards and arborist's saw, to collect seeds from native plants. Once they've preserved these plants' genes, what next? Will someone use them to breed more resilient plants, to plant new woodlands? No one really knows yet. All they can be sure of, as they lace up their boots and start down a lane, is that change is coming, and it may be that the window in which they can collect the seeds of these plants here is almost closed.

THE ASH TREES OF ENGLAND are dying. They are preyed upon by a fungus brought from Asia, and estimates are that up to 80 percent of ash in the United Kingdom will die in the next decade. The oak, whose towering presence has been a constant in U.K. history, is also struggling. A complex of diseases, both bacterial and fungal, and erratic temperatures are taking

their toll. The ash tree above us is seriously ill. The local forester—Bedford Purlieu is owned by the U.K. Forestry Commission and managed by Forestry England—thinks it will go in the next year or two. Negri, who for two years worked on a Kew project to see if there were any disease-resistant ash that could be used to repopulate the woods, says that the carnage was unfortunately nearly complete. “Many trees initially identified as potentially tolerant ended up dying in the National Archive of Tolerant Ash as the years went by,” she says. It is likely that, as with the elm trees, which went before them, the ash are on the way out.

In 25 years, the climate in England is predicted to be warmer and dryer; London is projected to be similar to Barcelona today. Kew has been researching where to find trees that might live in the England of the future, Jeffery tells me. They are having to look to Spain and other warmer climates to find them. That means that time may be swiftly running out here for some of the species around us, and as I walk up a dirt lane, I try to fix this image, this time, right now, in amber in my mind. Coppiced hazel trees form columns of staves in the golden undergrowth, and curtains of clematis and ivy drape the roadside. This lane appears on medieval maps, Jeffery explains, as one of a set of roads radiating from the wood's center. At the heart of the woodland was a circular crossroads, with an oak planted in the center. The roads were for charcoal burners, woodcutters, smelters. The Romans used this wood for smelting fuel. Later, in the early 20th century, it was largely cut for commercial timber. Now it is beech, oak, ash, hazel, hawthorn, blackthorn, dogwood, linden, viburnums, bluebells. Peering through the thicket lining the lane, I catch glimpses of an emerald green space, deep within.

Jeffery used to tend the alpine plant collection at Kew Gardens, leaning over beds of gravel inhabited by flattened, miniature growing things. Since he switched

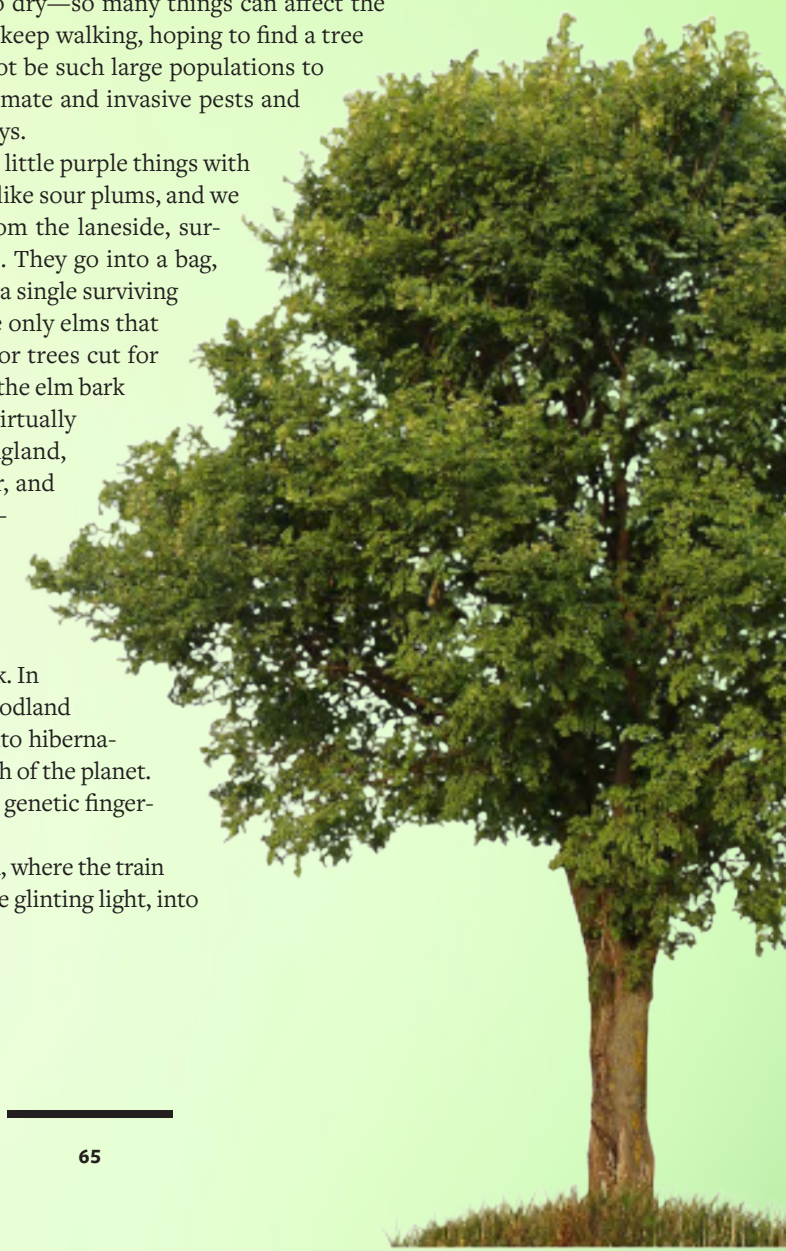
I remember seeing a lone elm once in a Connecticut wood. It felt like an emissary from some past era.

to seed collecting, he jokes that he went from looking down all the time to looking up, and has had to retrain his neck muscles. He is looking today for the blackthorn tree, or sloe, and one of the native dogwoods, a pert little tree with black berries. He slices open the dogwood berries with secateurs, to check if there is a white seed within. At first glance, over half the slots in the berries where seeds should be are empty. It may have been too hot, too wet, too dry—so many things can affect the set of seeds. He and Negri look worried. They keep walking, hoping to find a tree with a better yield. In the future, there may not be such large populations to collect seeds from. “We do not know what climate and invasive pests and diseases may be around the corner,” Jeffery says.

The sloes are looking good, however, plump little purple things with a white bloom. When he cuts them, they smell like sour plums, and we spend the next three hours plucking them from the laneside, surrounded by the calls of blue tits and red kites. They go into a bag, labeled with our initials and the dates. We spot a single surviving elm tree, and Jeffery points out that nearly the only elms that have survived have small trunks, young trees or trees cut for hedges. Big trunks are vulnerable to the insect, the elm bark beetle, that spreads the fungal disease that’s virtually eradicated elms from forests not just in England, but around the globe. We look at this survivor, and I remember seeing a lone elm once in a Connecticut wood. It felt like an emissary from some past era.

As the sun gets lower, the light pours through the upper branches of the trees, and we pack up the secateurs and sloes and walk back. In the vault of the Millennium Seed Bank, the woodland trees of today, or at least their genes, will go into hibernation. Perhaps they will be planted in the far north of the planet. Perhaps there will be woodlands there with the genetic fingerprint of the Bedford Purlieus Wood.

It’s time for me to head back to Peterborough, where the train station is. I go out from the darkling wood to the glinting light, into the fiefdom of corn.





IN THE CAR ON THE WAY to Peterborough, I find myself thinking of a marine ecologist on the other side of the world. Caroline S. Rogers lives in a bungalow high in the woods on St. John, in the Virgin Islands and is now an Emeritus Scientist at the United States Geological Society. I interviewed her nine years ago about a strange and lovely place near her home called Hurricane Hole. A warren of mangroves lines this bay in the Virgin Islands Coral Reef National Monument. These trees have roots like cathedral arches, and for years, corals of more than 30 species came and made their homes on the trees. The year I met her I swam out to see them. They were like nothing I'd ever seen, tiny colorful growths spangling the roots. There was hope that the mangroves might be a refuge for corals unable to live in warming waters.

When I saw her again, seven years later, much of the mangroves and corals had been destroyed. Rogers looked haggard as she told me. Two catastrophic hurricanes had struck the bay in quick succession, with high winds tearing up the mangroves. When I went to the water's edge myself, it was like there had never been a place like the one I saw, never been a fairyland where corals might have been saved. At the same time, around

the Virgin Islands, a new coral disease was ravaging the reefs, killing corals that were many decades old in a matter of weeks, even days. "I just never anticipated that the reefs would look like this," Rogers said.

She took out a book of essays by the late nature writer Barry Lopez. "Is it still possible to face the gathering darkness ... to embrace fearlessly the burning world?" She put the book down in her lap and looked ahead of her toward Hurricane Hole.

"This place has gone through a lot, and it's diminished in many ways," she said. "But it's also still incredibly beautiful. That's one of the things I'm trying to reconcile in my mind." She went to Raja Ampat, Indonesia, she told me, to snorkel there with her sister, far from the coast and shipping lanes, and was shaken by the beauty and vigor of healthy, intact reefs, still alive. It gave her heart somewhere to stand, when she came home to the declining reefs of the Caribbean.

Maybe this is why I am in somebody else's forest, watching somebody else's heart break. In Bedford Purlieus, I said to Negri, I don't go home anymore, because it is always burning. It is too hard to remember what it used to be like. More than a decade ago, the technology

ILLUSTRATION BY MATT GIBSON

At a strange and lovely place called Hurricane Hole, a warren of mangroves have roots like cathedral arches.

writer Christopher Mims wrote a short essay that I have never been able to forget. He pointed out that maybe once landscapes changed slowly enough that you might not notice that, from generation to generation, the conception of what nature should be was changing. Now that is not possible. “Any attempt to talk about the 21st century without acknowledging that every living thing on the planet will be altered by humans is intellectually bankrupt,” he wrote.

I looked up at where an ash tree used to be. “If you didn’t know about the before,” I said to Negri, “maybe it wouldn’t bother you?” She looked up, too. “But it’s happening so rapidly, you can’t not know the before,” she said. “The before was about two seconds ago.”

IN PETERBOROUGH there is a cathedral. But the cathedral came before the town. More than 1,300 years ago a king of Mercia converted to the worship of a foreign god, founding a monastery on a rock in a marsh. Two hundred years later, Vikings came, sacked the place; someone rebuilt it. Time passed. The monks lived off the marsh eels.

After another total destruction, the monastery began a great rebuilding in the 12th century. It took 125 years, across the lifetimes of five abbots, to raise the structure that stands today. Before I leave Peterborough, I make my way to its front.

It is gigantic, the largest, most imposing thing for miles around. But the cathedral feels like a pastiche, built by many hands. The three great arches that make up the west side are beautiful oddities, something that made sense at the time, to someone. They seem, to my eye, to lean forward, as if they were never properly attached to the facade, and a security guard tells me that the Victorians pinned the arches on, using metal.

I tell him it is bell ringing practice night, and I want to meet the cathedral’s band of ringers there in an hour. He brings me into the dark vastness. Inside, the patchwork quality, the sense of something built over

great time by many hands and without one cohesive plan, continues. There is a stone carving thought to be from an early iteration of the monastery, showing monks fleeing. There is an ancient clock, the size of a room, with no face—it was designed to make a sound every half hour, to help the monks keep to their order’s timetable. The guard shows me the grave of Katherine of Aragon, the wife Henry VIII broke with the pope to rid himself of. Her tomb was razed in the English Civil War, centuries later. Then more than a century after that, some Victorian Daily Mail readers named “Katherine” paid for a modest black marble slab.

Were the Victorians a blessing or a curse? I ask the security guard, as we walk outside. Is it good or bad that you can see their fingerprints everywhere? The cathedral is always changing, he says, looking up at the face of the west gate, glowing in the sunset. They did the best they could.

Up in the tower, I pull on a rope thick as a young tree, and feel the bell turning above me on its axle. I keep my rhythm as best I can, weaving a pattern of sound with the strangers who surround me, each pulling on their own ropes. I follow the ringing master out, and she tells me the bells, in fact, are new. They arrived in 1986, most of them from somewhere else, another church whose time was over. She lets me out of a thousand-year-old gate. Some men who are unhoused live there now. I walk to the train immersed in a gale of bells, as the practice continues.

Mark this moment well, this precise arrangement of the orrery of time. Once we were all here together, the oak, the ash, the hazel, dogwood, linden, hawthorn, the coral, the mangrove. Once there was a cathedral in Peterborough; once there was a wood by the A47. ☺

VERONIQUE GREENWOOD is a science writer and essayist. Her work has appeared in *The New York Times Magazine*, *Smithsonian*, *Discover*, *Aeon*, and many more.

Back to the Galapagos

A visit with evolutionary biologists Peter and Rosemary Grant

BY JONATHAN WEINER



T HIS PAST FALL I sat down with evolutionary biologists Peter and Rosemary Grant to talk about their new memoirs. We met at their home in Princeton, New Jersey. The three of us hadn't had a long conversation for quite a while—not since they published *Forty Years of Evolution*, and that was 10 years back.

I first met the Grants in January 1990. I had heard a little about their extraordinary work, and I wanted to write a book about it. Every year, they spent months camped out in the Galapagos Archipelago, Darwin's islands. There, on an impossibly bleak speck of rock called Daphne Major, they studied Darwin's finches, the birds that helped lead him to his theory of evolution by natural selection.

To everyone's surprise, including their own, the Grants had discovered that they could watch Darwin's process in action. In the first pages of the *On the Origin of Species*, Darwin argues that evolution by natural selection goes on all the time, "daily and hourly." However, he writes, the action is so geologically slow that you would need "the lapse of ages" to see it happen. That turns out not to be true. The Grants have witnessed an amazing amount of action—including the origin of a new species.

When we met, Peter and Rosemary were already famous within their field, but they were virtually unknown outside it. For several years, I lurked around the Princeton biology department where they taught, visited them on Daphne Major, interviewed their students, and pored over their research papers. I think the Grants both felt a certain amount of relief when my book, *The Beak of the Finch*, was finally

published, in 1994. But I knew we were going to be OK when they invited my wife and me to the backyard wedding of their older daughter. (Their two girls had grown up, in part, on the slopes of Daphne Major.)

So now it was a sentimental journey to visit them once again. It was a bright, warmish morning in October. Rosemary had just turned 88, and Peter was about to turn 88, too. To me they seemed pretty much unchanged, still as charming and almost as vigorous as ever, although Rosemary had to interject now and then to help Peter with his hearing. ("Being deaf, or semi-deaf, I miss key words," he said.) The house looked unchanged too, except for new solar panels. No sign anywhere of all the awards that have been showered on them in the past 30 years.

And now they've written their memoirs. For the Grants, that *is* a change. Back in the '90s, when I was cadging interviews with them, they were so focused on the finches that they didn't seem to realize that their own lives might be interesting, too. I'll never forget the day I asked Peter to talk about his childhood. He told me, rather tersely, that as a little boy in the English countryside he'd once tried to catch a blue butterfly by hand. Then he ended the interview. He had to be getting back to work. He was very busy, he said. "But *you* seem to have all the time in the world."

SCIENCE ON AN ISLAND

Peter and Rosemary Grant on Daphne Major in 1991. In those days, the only way the Grants could write to the outside world was by handing a letter to a passing fisherman, or to one of their very rare visitors. In this case, the visitor was Jonathan Weiner.



Having read his memoir, I understand his reticence at that moment.

The three of us had lunch, then moved to the living room, where Rosemary put out a pot of tea and a tray of McVitie's biscuits, and we talked all afternoon.

Jonathan: I want to start with the memoirs. Having known you all these years, to hear all these stories is a delight.

Peter: That's kind of you to say so. Because what one writes goes off into the public realm, and then there's a *silence*. A few people will say, "Oh, I really like it." But more say, "I'm *so looking forward* to reading your book."

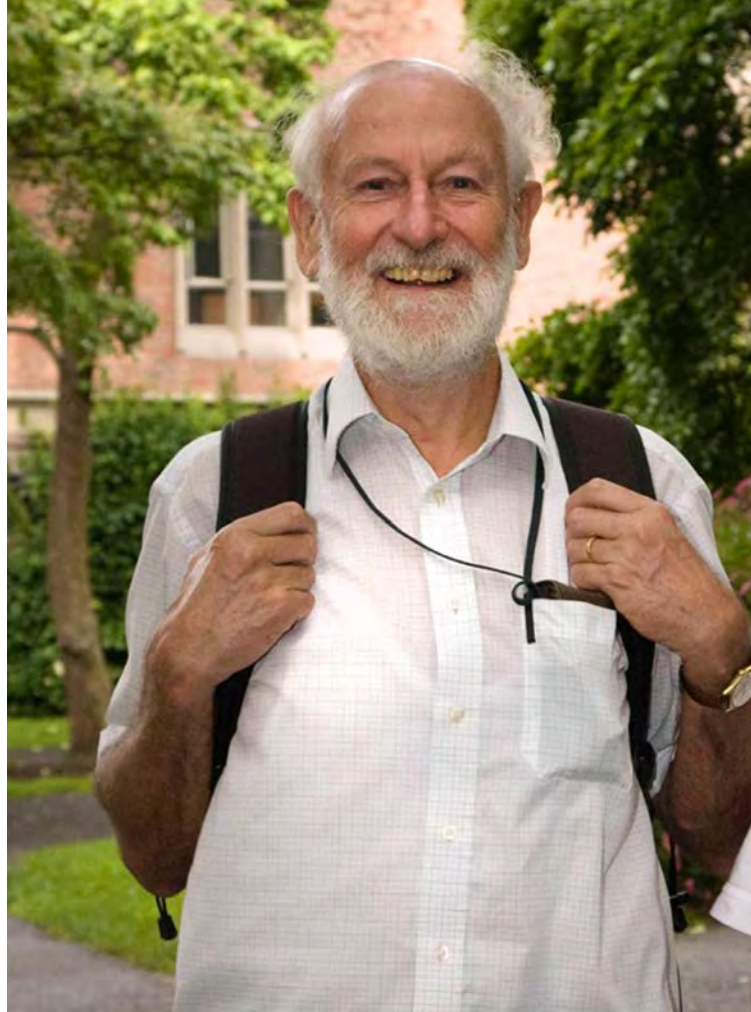
Rosemary: Or they'll say, "It's *on my pile* ..."

[laughter]

Rosemary: I had a peculiar feeling when I was writing about my childhood. I found that I was spelling everything in the English way, which I've never done before. I was writing as a child. It was almost as though I had completely gone back, you know, 80 years or something. It was a weird sensation. And—

Peter: M'dear, if I could interrupt, and let you carry on in a second—I had a very different way of thinking about my childhood, which was that I was an *observer* of a little boy running around. So although I was him, I was also an observer of him. It was peculiar, I've never had that impression before. So, back to you ...

ROSEMARY GREW UP in the coastal village of Arncliffe, in England's Lake District. Her father was the village doctor. "Throughout my childhood," she writes in her memoir, "horses were used to plow the fields and deliver milk and coal ... In the 1930s, the village had three telephones, the numbers being 1 for the pub, 2 for the vicar, and 3 for the doctor, my father." As a child, she loved roaming the countryside hunting for fossils and watching all the waterbirds ("turnstones, redshanks, curlews, sanderlings, shelducks, and Greylag geese"). When she was at home, she trailed around after the family gardener, Jeremiah Swindlehurst, asking questions. Why, for instance, weren't all of the



cabbages in the same row exactly alike? Why weren't all the birches alike, or the oaks, or the robins, or the finches?

Rosemary: I kept asking Jeremiah—such a wonderful name—why was there so much variation? He said, "Oh, well, it's all due to the environment." He showed me how things grow differently in the sun and in the shade, that sort of thing. And then my father also answering it by saying, "Yes, everybody's different, and I have to take this into account when I'm giving people medication."

So I was fascinated with this problem of variation. I remember playing a game at home with my brothers. John had black hair and brown eyes. I had brown hair and greenish eyes, and my little brother, Andrew, had fair hair and blue eyes. And we would say to our parents, "Well, if you have another child, what's it going to be like?"



LIFE'S WORK Peter and Rosemary Grant pictured outside Eno Hall on the campus of Princeton University. The two of them met as graduate students at the University of British Columbia in 1960. In 1973 they began their life's work together on *Daphne Major* in the Galapagos.

But then, at the same time, I was a girl. Back then, if you were a girl, the whole education process was geared to you getting married. You learned how to look after a house and look after a family, and that was it. That was it.

PETER WAS BORN in a suburb of South London. When he was 2 years old, his parents separated, and later divorced. "I was awarded by the court to my father, who was the 'wronged party,'" he writes in his memoir. When he was 4, he was sent out to the countryside to escape the London Blitz. Between the ages of 4 to 8, he was boarded in a school in Surrey.

He fell in love with nature in a nearby park and down in a pit in front of the school, which they called The Dell. The pit had been formed by a bomb dropped by a German plane early in the war, and it was now as lush as a meadow. That was where Peter chased that blue butterfly—in The Dell. Many child evacuees from that time felt abandoned by their parents. "If I felt the same," he writes, "the feeling and memory have been lost in the mists of time." Birds, butterflies, and flowers became bright spots during years so bleak that he hardly talked about them until he reached the age of 60.

Peter: I'm really intrigued by the fact that I just absolutely worshipped nature, right from being knee high to a grasshopper—yeah, grasshoppers, amongst many other things. And why?

All my schoolmates when I was 4, 5, 6, 7, out in the country—they were inside when I was outside looking at swallows flying around and looking where the birds were nesting and wondering if I could climb the trees to get there, that sort of thing. I mean, a typical little child naturalist.

And where did I get it from, when it was not my parents? My father was actually a little bit scared in the countryside. My mother never had any feeling for the countryside, either, and neither of them had any

When I was 12, my father said, if you're so interested in biology, why don't you read Darwin's *Origin of Species*? We didn't have it in the house. So I went all the way into Kendall on the bus to get it from the library, came back, and read chapter one, all this boring stuff about pigeons. I thought, "Oh, Lord, this is not what I'm interested in."

My parents were very good. My mother said, "Okay, well, we'll go and see a pigeon breeder." And then pigeons became fascinating, because the breeder had his pouter pigeons and fantails and tumblers and all the things that Darwin had talked about. And what really blew my mind away was that pigeons had been used to take messages to the front lines in the war. And Julius Caesar had done this, too.

My parents were always very good when we asked questions—not just explaining things simply, but going into the answers in depth. That's wonderful.

influence in showing me plants or identifying a butterfly. So I didn't get it that way. I didn't get it from any of the teachers at this school, either. But I was naturally predisposed, even then, to look at flowers and admire their pretty petals, identify butterflies and try to catch them, even at a very early age. And so that remains an enigma to me.

ROSEMARY HAD TO STRUGGLE fiercely to get a good college education. By force of will, she made it to the University of Edinburgh, where she studied with Douglas Falconer, a world authority on quantitative genetics, the study of variation in animals and plants.

Peter went to Cambridge, where Darwin had studied more than a century before.

The two of them met as graduate students in 1960. They were in their mid-20s, two young biologists at the University of British Columbia, in Vancouver. When they first bumped into each other, as Peter recalls the scene, he was carrying a pair of skis.

"Those skis are too small for you," Rosemary said.

"No, they are not," said Peter.

"Yes, they are, I can see just by looking at them."

One year later they were engaged. The next year they were married in Rosemary's village, Arnside. As they stood on the altar, Peter whispered in Rosemary's ear, "I heard this morning that the DNA code has been cracked." The newlyweds spent part of their honeymoon in New York City, measuring bird specimens in the American Museum of Natural History.

BIRD IN THE HAND Peter and Rosemary Grant in 1991. Daphne Major is the cinder cone of an extinct volcano, and the Grants are sitting on its rim, measuring finches. Jonathan Weiner took this picture when he was doing research for his book *The Beak of the Finch: A Story of Evolution in Our Time*, and this is a scene he describes in the first chapter.



JONATHAN WEINER

In 1973, when they began their now-celebrated study of Darwin's finches, they didn't know they'd found their life's work. They thought they'd be working in the Galapagos for just a few years. The breakthroughs that the Grants and their students made there have been described many times in the Grants' books and papers, and in my own book, and most recently in a second edition of *Forty Years of Evolution*, which adds yet another decade to one of the most remarkable long-term projects in the history of science.

I asked the Grants to do a very quick summary of the highlights of their research.

Peter: Number one is the discovery that evolution occurs and is study-able *within our time*. Number two is the discovery that hybridization and backcrossing, although rare, does occur—

Jonathan: I'm sorry, Peter, but "hybridization and backcrossing" will be Greek to non-specialists.

Peter: Put into different language: Species A breeds with Species B, which is hybridization.

Rosemary: On Daphne Major, we saw *fortis* mate with *scandens*. [That's *Geospiza fortis*, the medium-beaked ground finch, and *Geospiza scandens*, which is a cactus finch.] They were hybridizing at a very low frequency, a really low frequency, only about 1 or 2 percent of the time. Under good conditions, when there was lots of food on the island, the hybrids actually survived, and then they bred with one or the other of the parental species. And that's backcrossing.

Peter: By backcrossing, a hybrid's genes can flow back into one of the parental populations.

Rosemary: Often the reason they hybridize is that they learn the song of the other species. They learn to sing while they are little birds in the nest, during a very short, sensitive period of time. If, during that sensitive period, the father dies and the young in the nest hear the song of a neighbor, and the neighbor is another species, then the young birds will learn *that* species' song. Learning the wrong species' song leads to hybridization.

Jonathan: Right. So we're marching through your list. That's number one and number two. What's number three?

Peter: Number three is the Big Bird story, which is a story of *speciation* by hybridization. It's a story that starts with the arrival of a mysterious bird on Daphne. We thought it looked like a *fortis* but didn't sing exactly like a *fortis*, and it did not have exactly the same proportions either. Later, a genomic study revealed that this bird was *not* a *fortis*, it was a *conirostris*.

Rosemary: It was a pure *conirostris* from Española, an island far away in the southeast part of the archipelago.

Peter: This Big Bird bred with *fortis* on Daphne. So here was another case of hybridization. And after two generations, the offspring were breeding amongst themselves and not with *fortis* anymore. They were behaving essentially as a separate species.

Rosemary: We followed them for three more generations, all breeding amongst themselves. So they were completely separate from all the other species on the island, and they sang a different song. Big Bird had brought his song over with him. They all sang the original Big Bird song, and they were different in size and different in beak shape.

Jonathan: In your view, how important is hybridization in the origin of species?

Rosemary: It's very important. Now that we have looked at the genetics of the whole group of Darwin's finches, we think this has probably happened quite frequently in the past. We think now that these sorts of events have been winking in and out, and in and out, and sometimes leading off to a new species.

We think this is a very common phenomenon, not just in finches but in all organisms, including everything from viruses to all animals.

Jonathan: That's fascinating.

Rosemary: And think of cancer. The similarity is strange; but if you think of cancer in the colon and



FORTY YEARS OF EVOLUTION Peter and Rosemary Grant at work on Daphne Major in the Galapagos Islands, capturing and measuring finches from the genus *Geospiza*. This work led to many breakthroughs in our understanding of evolution, which the Grants sum up in their book *Forty Years of Evolution*.

cancer in the lung, let's say, the cancer is dividing in two very different ecosystems. It's like the birds multiplying on different islands with different ecologies. So you have cancer cells in the lung and the colon, and then they meet: They go through the blood system and fuse together, and multiply, and you get a different cancer.

THE GRANTS RETIRED from teaching at Princeton in 2008, and their last visit to Daphne was in 2019. For years now they've been fortunate to be able to continue the finch-work from home, collaborating with a stellar team of genomicists at Uppsala University in Sweden to learn whatever they can learn from the DNA of Darwin's finches.

First, Swedish geneticist Leif Andersson and his team in Uppsala sequence the whole genome of a finch from the DNA samples that Peter and Rosemary supply.

The sequencing machines determine the nucleotides of each and every chromosome throughout their length. Then Andersson and his colleagues can compare the chromosomes of two individual birds point by point to find places where they differ and where they are the same. They might compare and contrast two *fortis*, let's say, or a *fortis* and a *conirostris*. "It's like holding up two strings side by side and seeing where they match and where they don't," Peter says. "The *don'ts* are informative. They tell us where the species differ most."

I asked Peter and Rosemary for a brief summary of the work they've done with Leif Andersson.

Peter: Our association with Leif started in 2012 with a small paper about color polymorphism in the beaks of the finches. That led us to ask, with his help and his expertise, much broader and deeper questions.

K. THALIA GRANT

Genomics has revealed a great deal of finch history: that is, which species are related to which, how they are related, and how the pattern of relatedness unfolded through time. We found good reason for thinking there are more than the 14 species that we'd thought were there. We split a few, and finished up with the number 18.

[Here Peter paused, staring out the window.] Excuse me, I'm being sidetracked by a mockingbird over there. Oh, it's gone into the holly bushes.

Rosemary: The breakthrough was getting blood. Fortunately, we had taken blood samples from every finch that we had measured since 1988. So one of the things we now know is that the whole radiation of the finches is really quite young; it's between 1 and just over 1 million years old. Secondly, there is a burst of radiation about 250,000 years ago.

Peter: You get this sudden burst of radiation.

This was a time of great climatic disturbance in Earth history. It's a time when there's a big oscillation twice over: from full glacial conditions to full interglacial conditions and back again.

We're familiar with the Last Glacial Maximum about 120,000 years ago. Well, that was a single peak, as it were, in conditions. But about 200,000 to 250,000 years ago, there was a *double* peak. And so, at this time of great environmental upheaval, we think that maybe conditions favored—in ways that we can only guess—the splitting of lineages into more species. The fact is that seven out of the 18 species of Darwin's finches originated at that time, according to the genomic work.

These studies also told us that hybridization, which we have been studying in contemporary time, has been going on for a very long while, maybe close to a million years. One of the early branches of the finch family tree, one of the warbler finch groups, is genetically similar to other species that were formed later, in ways that can't be explained just by common inheritance, but must be explained by exchanging genes.

We also confirmed that during a drought, when survival was at a premium, natural selection acted not only at the phenotypic level—that is, on the measurements of the beaks—but at the genotypic level as well.

Rosemary: So that was really nice. The genomics work matched absolutely exactly what we'd shown in the field. It's wonderful to see the genetic underpinning of what we had seen in the field.

Jonathan: That's amazing.

Peter: With the Big Birds, of course, we'd love to go back to the island and find out what has happened since we were there. A postdoc from Leif's lab did go back, and took blood samples, and measured birds as well. But we haven't got the sequences yet, so we can't say anything.

WE TALKED ON as the sun began to set. The Grants had much more to say about genomics, plate tectonics, ocean currents, hybridization, the genes that shape birds' beaks and human faces, and, of course, the origin of species. Among many other things, the genomics work has revealed that Darwin's finches are not really finches at all. Officially they are now classified as tanagers. In the northeastern United States, their most famous relative is the scarlet tanager, which lives in the crowns of trees, singing a song that is sometimes described as sounding like "a robin with a bad cold."

Before I left, I asked a question that I'd first asked the Grants back in the 1990s. Is there any sign that climate change is now disrupting the course of evolution in the Galapagos Islands? Peter told me that there are changes in the Pacific, but the signal has not yet been detected on land, mostly because the archipelago lies right at the equator.

Peter: Someday somebody will be able to put together a large amount of data and say, "Yes, we're just beginning to see some effect." But it's very hard to predict what will happen—other than that the islands will be *changed*. Yes, maybe there will be a signal in the terrestrial environment as well, by the time we leave the planet. ☺

JONATHAN WEINER teaches science writing at Columbia Journalism School. His book *The Beak of the Finch* won a Pulitzer prize in 1995.

Why Do Animals Adopt?

Taking responsibility for another's young reveals the deep evolutionary roots of care

BY SARAH DEWEERDT



THE GIR FOREST, a sere landscape of teak, acacia, and jujube trees in western India, is home to the world's last remaining wild Asiatic lions. Park rangers track the 650 cats' every move to protect them, and scientists have been following the endangered population's triumphs and tragedies since the mid-1990s in one of the longest-running carnivore studies in Asia.

In December 2018, rangers spotted a Gir lioness with an odd litter of cubs: One of them was a young leopard. "I got the information, went there, and just couldn't believe my eyes," says Stotra Chakrabarti, a behavioral ecologist at Macalester College in Minnesota, who was then a graduate student doing field work in the area.

Lions and leopards compete for the same resources, so the usual reaction of an adult of either species encountering a youngster of the other would be to kill it on the spot. But for the next 45 days, the rangers and researchers watched as the leopard cub nursed from the lioness, noshed on kills she made, and romped with his adoptive lion siblings.

This offbeat family idyll was short-lived: In February 2019, the leopard cub turned up dead near a watering hole. His small body looked perfect from the outside, unscathed, but an autopsy revealed a femoral hernia—a birth defect that may have caused his biological mother to abandon him and eventually led to his death.

Years later, Chakrabarti remains "completely stumped" by the unusual adoption. "I will probably never see this again," he marvels.



DIFFERENT STRIPES This lioness cared for this leopard cub like one of her own offspring.

The word adoption “is very anthropomorphically charged,” Chakrabarti acknowledges. Adoption is known widely in human societies but is more likely to be thought of as a behavior that sets us apart from other animal species rather than a practice that unites us. Yet relationships in which an adult animal takes on a parental role for a young one that is not her or his own offspring, while rare, are widely documented across the animal kingdom. Sea otters adopt, as do elephant seals, gulls, dolphins, elephants, cheetahs, penguins, storks, African wild dogs, and a whole troop of primate species.

Such relationships seem like an evolutionary paradox at first glance. Feeding and protecting a juvenile is costly. Evolution is supposed to be about the promulgation of one’s genes; why invest time and energy in the survival of another’s, potentially at the expense of your own? Yet animal adoption may also illuminate the underpinnings of a sensibility common to humans and other animals.

MOST ANIMAL ADOPTIONS occur within species, often within extended family groups. Orphaned chimpanzees may be cared for by older siblings, and among red howler monkeys in Venezuela grandmothers sometimes step in to care for a daughter’s infant. These observations are easily explained by the evolutionary principle of kin selection, which holds that seemingly altruistic behavior is evolutionarily advantageous when it benefits an individual’s relatives, who after all share many of the individual’s genes.

But sometimes the connections underlying adoptive relationships are more nebulous. When a young mountain gorilla loses their mother, the rest of the troop comes together to support them. This includes older siblings, same-age peers, and especially the troop’s dominant male, who will often share his nest to help the youngster stay warm at night.

“Care for the orphan does particularly fall on the dominant male,” says Robin Morrison, an evolutionary

COURTESY OF MITTA, D., ET AL. ECOSPHERE (2020)

Such relationships seem like an evolutionary paradox at first glance.

biologist at the University of Zurich in Switzerland who also works with the Dian Fossey Gorilla Fund's Karisoke Research Center in Rwanda. Even if the male is not related to the adopted juvenile, he and his genes may benefit: Female mountain gorillas prefer to mate with males who are good with babies.

Animals sometimes adopt unrelated young even from outside their community. Researchers at the Luo Scientific Reserve in Wamba, Democratic Republic of the Congo witnessed two cases in which female bonobos adopted infants from neighboring social groups. Similar behavior has also been seen in Angola black-and-white colobus monkeys and Taihangshan macaques.

Those adoptions are hard to square with classic evolutionary theory. Harder still are cross-species adoptions. In addition to the lioness who adopted the leopard cub, scientifically documented examples include a troop of capuchin monkeys taking in a baby marmoset; a bottlenose dolphin caring for a melon-headed whale calf alongside her own baby; and an Icelandic killer whale seen traveling alongside a long-finned pilot whale calf. And amateur observations of cross-species adoptions—cats adopting puppies, dogs adopting fawns, and so on—abound in the form of cute animal videos on the internet, suggesting that the propensity for these relationships may be much more widespread than had previously been acknowledged.

AMONG LAKE ERIE'S RING-BILLED GULLS, who breed in large, chaotic colonies, about 8 percent of chicks leave their natal nest each year, sneak into a nearby one, and are accepted by the neighboring parents. This so-called reproductive error, a kind of glitch whereby animals become confused or fail to discriminate between other offspring and their own, is frequently invoked to explain animal adoption. In the big evolutionary scheme of things, it seems, it's better for gull parents to occasionally raise a chick that's not their own than to be hypervigilant about interlopers, which could sometimes result in pushing their own young out of the nest.

A similar hullabaloo characterizes the elephant seal birthing colony at Año Nuevo, California, where one-quarter to one-half of pups each year become separated from their mothers due to storms, high tides, or the disruptive movements of galumphing males. About one-quarter of these "orphans" are subsequently adopted or frequently cared for by other females. Most often, the adoptive mothers have lost or become separated from their own pup, and many of them are young and inexperienced. (The Gir lioness, too, was relatively new to motherhood, raising only her second litter of cubs, when she adopted the leopard.)

Lack of experience may contribute to the failure to discriminate between one's own and other young, but researchers have suggested another benefit to

Maybe our tendency is to look at evolutionary forces too narrowly.

adoption for these mothers: It's good practice, yielding improved parenting skills that help the animal's own young later on.

Surging maternal hormones may contribute to a new mother's willingness to take responsibility for an unrelated mouth to feed, either in addition to her own young or as a substitute if she has recently lost a baby. Most of the time, an animal's intense maternal instincts will be directed at her own offspring, says James Serpell, professor emeritus at the University of Pennsylvania School of Veterinary Medicine. But every so often, she'll simply "glom on to whatever comes in handy." This may sometimes lead to *Raising Arizona*-style capers documented in the scientific literature in which animals adopt young who don't actually need adopting—a Tibetan macaque mother, for example, who had recently given birth, kidnapped another infant and ended up raising both babies as her own.

In the southwestern United States, biologists working to restore endangered Mexican wolves have put these widespread proclivities to use in a fostering program that places captive-born wolf pups into wild dens with litters of the same age.

"We rub them all together in this little puppy pile" so that captive-born pups acquire their newfound siblings' scent, explains Allison Greenleaf, a senior U.S. Fish and Wildlife Service biologist on the Mexican wolf recovery program. Then the new, expanded litter is put back in

the wild den. Mother Nature—or mother wolf, with assistance from the rest of the pack, who cooperate to raise a single breeding pair's litter—does the rest.

The fostering program, the researchers hope, will enrich the genetic diversity of the wild Mexican wolf population, which is descended from just seven captive-raised individuals. It's also thought that wild-raised pups will be more wary of humans and thus less likely to become nuisance animals than captive-raised wolves released into the wild as adults, Greenleaf says.

Since 2016, 126 captive-born Mexican wolves have been fostered into 48 dens, and at least 20 have survived to reach breeding age at 2 years old—a survival rate comparable to that of wild-born pups raised by their biological parents. Fostered pups have produced 30 litters of their own, and some have even become foster parents themselves.

Adoption may be more complex, but also simpler, than this search for evolutionary explanations makes it out to be. People reflexively look to immediate biological advantages as a rationale for animal behavior, says Judith Benz-Schwarzburg, an ethicist at the University of Veterinary Medicine in Vienna, Austria. But adoption shows that other animal species, especially those who care for their young, are "driven by lots of reasons"—just like humans are.

Chakrabarti, the biologist who studied the leopard cub-adopting lioness, would agree. Animals are

not “automatons,” he says. “Each of them are rational, sentient beings,” with individual agency, preferences, and personality. We may never know why some feel moved to adopt.

Or maybe our tendency is to look at evolutionary forces too narrowly, on too fine a timescale. Humans and other animals with extended parental care have “had hundreds of thousands of years of evolutionary pressure to care for infants and look after them,” Morrison says. “Having strong caring instincts has been really valuable across our evolutionary history.”

Those evolutionary forces will be especially strong in the case of species, like our own, that exhibit cooperative parental care. Perhaps that helps explain why we’re the absolute champions at cross-species adoption. Although dogs and cats might have started as working additions to households, many have become more akin to “fur babies,” as the contemporary term goes; in many hunter-gatherer societies it’s common for people to bring young animals into the village and raise them as pets. This behavior may be “a natural consequence of a human propensity to care for other individuals,” as Serpell puts it.

In fact, one theory of dog domestication holds that the process began with Pleistocene hunter-gatherers bringing young wolf pups, perhaps orphans, back to camp to be suckled by human women and raised as part of the community.

An early domestication of dogs might have even facilitated other cross-species adoptive relationships. “I strongly suspect that the capacity of a nursing mother dog to accept puppies that aren’t her own may have helped in the domestication of the cat,” Serpell says. “Adult dogs are not very accepting of cats, and it would have been difficult to domesticate cats in a community that already had dogs. But if you had a nursing mother dog, you could certainly foster a kitten onto her and she would adopt it.”

Several thousand years later, these phenomena remain embedded in our daily lives. Consider the three cats who live in my house: two full sisters and a half-sister who is a few months older, we’ve been told, with a founding backstory involving a plastic tote in the woods. As in orphan chimpanzee families, the older girl has become a mother figure for the younger two, grooming them, putting them in their place with a swat

when necessary, patrolling the ramparts of the windowsills for threats to her territory.

Sometimes I watch her, stretched out on her side in the pose of a nursing mother cat, the other two lying crosswise on top of her even though all three are now fully grown. In her posture, at once patient and resigned, I can see the echoes of a lioness in a clearing in the Gir Forest. I can see a half-wild wolf suckling a half-wild kitten, and I can see a fully wild wolf unfazed by the sudden growth in the size of her litter.

Then again, maybe my own devotion to the older sister, my desire to see the caretaker well cared for, also has something in common with that lioness. Maybe animal adoptive parents are not just a curiosity but a model for human behavior: we affectionate silverbacks, we Gir lionesses, weaving relationships both genetic and not, united by a drive to care. 🐾

SARAH DEWEERDT is a freelance writer in Seattle covering biology, medicine, and the environment.

The background of the entire page is a photograph of an archaeological excavation. It shows a cross-section of earth with distinct horizontal layers of soil and rock. On the right side, a person's hand is visible, holding a small, dark, rectangular tool, possibly a trowel or a small shovel, and is in the process of digging or clearing the soil. The lighting is warm and golden, suggesting a sunny day. The overall texture is rough and uneven, typical of an excavation site.

An Archaeological Reckoning

*Jennifer Raff is on a mission to rewrite the history of
human origins in the Americas*

BY ELENA KAZAMIA



WAS NOT ALLOWED TO see the bones of the dead when I visited Jennifer Raff. They were fragments of teeth and skulls held in a small metal cabinet in the basement of Fraser Hall, the University of Kansas' hub for anthropology research. The bones can be thousands of years old and belong to some of the earliest-known settlers of the Americas.

Raff, who practices martial arts, has a strong athletic build and a bright, unguarded demeanor. As we walked through the anthropology department above the basement, I noticed skulls of hominids in glass cases along the walls. So why were the bones in the basement so vigilantly out of limits?

Raff told me that Indigenous Americans typically regard the remains as sacred, belonging to their ancestors. Members of some tribes had granted Raff permission to study the genetic composition and origins of the bones. But she must do so discretely, keeping the remains hidden from visitors.

Raff, an associate professor of anthropology at the university, specializes in paleogenomics, extracting genetic material from ancient remains. The DNA preserved inside the remains has the power to vindicate or undermine carefully laid out archaeological theories about migration patterns, how and when people first arrived, and to shed light on how these early settlers lived their lives.

For years, Raff has studied how humans first set foot in the Americas. Her 2022 book, *Origin: A Genetic History of the Americas*, was praised by Dartmouth College paleoanthropologist Jeremy DeSilva for drawing together archaeology and Indigenous oral traditions “in a masterly retelling of the story of how and when people reached the Americas.”



IN HER ELEMENT Jennifer Raff on site, helping a colleague with an excavation in Kansas, where she lives and works.

Raff admitted that she was not always sensitive to the provenance of the ancient remains she studies. When she was working on her Ph.D., she analyzed DNA from a first-century burial site in Illinois without the consent of local tribes. She used rib bones belonging to deceased women and children to extract DNA and study relatedness. It was perfectly legal to use the skeletons, which were kept at Indiana University, but she now regrets doing so.

“In retrospect, I should have gone to tribes who claim descent from these populations, talked to them about the work, and gotten permission,” Raff said. “But at the time I thought, ‘Oh, it’s fine,’ so I just did it. That’s an attitude that I really push back against now with colleagues and other people in

the field, thinking you can just do this work without permission or engagement with descendant communities. I really regard my earlier work as very unethical. I won’t go back and publish any of it.”

Raff’s change of heart toward ancestral remains and artifacts represents a personal awakening for her. It also represents a generational shift in the practice of anthropology and archaeology. Raff’s mentor, Dennis O’Rourke, a professor of anthropology at the University of Kansas, said that in previous generations archaeologists rarely if ever consulted with Indigenous peoples. “There were no seeking permissions to do the work,” he said. “Most researchers relied on museums to provide permissions, and museums sometimes engaged in consultations and sometimes not.”

As Raff and I arrived at her office, she said, “One of my missions as a scholar in this discipline is to try to improve it. I can’t atone for the abuses of the past, but I can try to make the field better in my way.”

RAFF SAT AT HER DESK in her university office, pulling her dark hair into a ponytail behind her head. A framed photograph of Muhammad Ali boxing underwater in a swimming pool hung on a wall. A Rothko print in deep blues and reds hung on an opposite wall. Sitting on a bookshelf were prizes Raff has won for *Origin*, one of them from the American Anthropological Association for the best science book in the field of biological anthropology. They were joined by mostly popular science and adventure books from authors she admires: *In the Empire of Ice* by Gretel Ehrlich and *Control: The Dark History and Troubling Present of Eugenics* by British geneticist Adam Rutherford, a friend and mentor.

With the sun setting over the Kansas horizon, Raff told me it was a summer in the Arctic that shaped how she saw her own discipline. It was 2009 and she was a postgraduate, a geneticist invited to participate in the excavation of Nuvuk, an archaeological site located in Alaska's northernmost point. Ocean storms continuously erode the coast there, pushing the frontier of the land southward. The area is home to the Iñupiat, who have lived there for more than 1,000 years.

The dig that Raff joined was excavating the ancient cemetery at Nuvuk, which was rapidly eroding into the water, taking away with it the cultural and physical remains of the paleo-Inuit who were most undoubtedly related to the present-day inhabitants of Utqiagvik.

The Arctic landscapes left an indelible impression—the starkness of the open plains, the punishing swarms of insects, the winteriness even on the warmest days. “It’s a remarkable environment,” Raff said. The people whose genes Raff studies had survived this and harsher environments for at least a millennium. “I could really appreciate the innovations that kept them alive,” she said.

The scientists had sought permission to sequence the DNA preserved inside the remains unearthed at the cemetery through consultations with the Iñupiat of Utqiagvik. The community had agreed, provided certain provisions—minimal physical damage to the excavated bodies, followed by prompt reburial.

“It was liberating,” Raff said. “To work within an explicitly stated framework, composed by the descendants of the peoples I was hoping to learn from, made it easy to do our scientific research on their terms.”

Since the 1800s, anthropology museums have stocked their collections with Native American artifacts and remains sacred to tribes. “Native peoples were essentially powerless to stop it,” said Chip Colwell, editor-in-chief of *Sapiens*, an anthropology magazine, and formerly a senior curator at the Denver Museum of Nature and Science. “When I was coming up in the field in the ’90s, it was extraordinarily rare for Native peoples’ concerns, insights, practices, and religions to be considered as a part of archaeology.”

Human history belongs to all humankind, the rationale went, elevating archaeology and anthropology to the prerogative of enlightening all humanity. From that vantage point, the needs and views of a relatively small group, such as the Native Americans, seemed trifling, especially if they insisted on the reburial of discovered bones and artifacts. Reburial, rather than preservation of archaeological finds in museums, was seen as anti-science, prohibiting future investigations which might shed new light on history.

In 1971, road workers discovered a burial ground in Glenwood, Iowa. They uncovered the remains of 26 European-American “pioneers” and a Native American woman and her child. While the pioneers were reburied in a local cemetery, the Native American remains were packed off to the Office of the State Archaeologist in Iowa City, to be distributed to museums or universities. “Dead Native Americans were archaeological resources for the state and white people weren’t,” Colwell explained. “We had allowed Native peoples to become the subject of science in a way we hadn’t for other people.”

The Glenwood incident sparked a movement to defend Native American rights, challenging archaeological standard practice. In 1990, on the heels of the Civil Rights movement, the Native American Graves Protection and Repatriation Act (NAGPRA) was enacted into law. It gave

I can't atone for the abuses of the past, but I can try to make the field better.

Indigenous people the right to rebury their dead, provided they could make a tenable connection between ancient remains and tribal affiliation. Under NAGPRA, affiliation can be established via land ownership, so that remains discovered on federal or tribal land are recognized as belonging to the tribes themselves. At the time, Colwell said, passage of NAGPRA caused an uproar. "Some scholars equated reburial to book burning or destroying libraries of knowledge."

Gradually, the culture among archaeologists began to shift, thanks largely to Indigenous activism. "That began to really push archaeologists to confront the ways in which their discipline was perpetrating harm," Colwell said. He estimates that 90 percent of anthropologists and archaeologists today are on board with the law.

Raff said meeting tribal members and learning about their cultures from them is a boon to science. Scientists can't approach research questions, such as when humans first arrived in the Americas "with just one discipline's data and methods alone. You have to let multiple truths or multiple possibilities coexist at the same time."

RAFF'S COMFORT WITH AMBIGUITY deeply informs her work. Her central thesis in *Origin* runs contrary to the anthropology that has long been taught in classrooms, a tidy story of how the first people arrived on the American continent in a single wave of migration from Asia some 15,000 years ago.

Raff patiently unwinds this expectation, explaining how multiple disciplines and ways of knowing have, over the past two decades, converged on a richer, but muddier narrative of when humans first set foot in the Americas. The tidy Clovis-first theory held that people who settled the continent about 15,000 years ago were supported by a novel technology—a special kind of sharp spearhead (a Clovis head) that allowed them to hunt and subsist on megafauna. It was assumed that the "last glacial maximum," an ice age that lasted for 4,000 years (between 23,000 to 19,000 years ago), covered the land in deep, year-round ice sheets that prohibited settlers before then.

But studies of DNA from the oldest human remains unearthed in the Americas, as well as sequenced genomes of present-day Indigenous



KELP HIGHWAY The “kelp highway theory” holds that people may have arrived in North America from Asia over 15,000 years ago—via a land bridge over the Bering Strait—and lived on kelp and marine life along the Pacific Coast. Jennifer Raff writes this theory is echoed by Native American oral histories.

people, show that Native Americans are descendent from a single population, dating to somewhere between 25,000 to 20,000 years ago. This suggests there was a *refugium*—a hospitable nook where these ancestors survived—far from other human tribes roaming the plains of Asia over the same period.

There have been no confirmed human settlements that date to this time, although Raff believes the best place to look is underwater, not far from where she conducted her research in Nuvuk. Scientists know that during the last Ice Age, Asia was connected to North America by a land bridge across the Bering Strait, which may have had a climate mild enough to allow populations to flourish.

The genetic signatures also show a distinct spread of different tribes—a branching sometime between about 22,000 and 18,000 years ago. One branch, the Ancient Beringians, has no known living descendants. The other, known as the Ancestral Native Americans, gave rise to populations south of the Laurentide ice sheet, which cloaked the north of the continent, along a line roughly connecting present-day Seattle with New York City.

The Ancestral Native Americans spread quickly across the whole continent, with many populations splitting extremely rapidly from one another. In *Origin*, Raff explains how this has long baffled archaeologists because it is not consistent with a slow overland advancement of hunter-gatherer populations.

ETHAN DANIELS / SHUTTERSTOCK

Raff's thesis about the first Americans runs contrary to the tidy story taught in classrooms.

A hypothesis proposed by Canadian archaeologist Knut Fladmark in 1979 has gained significant traction in recent years due to the pairing of ancient DNA work and Indigenous knowledge. Fladmark argued that people could have migrated along a coastal route rather than an ice-free corridor inland. Further research by scholars, notably Jon Erlandson of the University of Oregon, has led to the theory that humans could have lived along the coast eating kelp, fish, shellfish, and marine mammals, traveling to new sites by boat, via a “kelp highway,” which ran north to south along the west coast of North America, a route that could account for the rapid spread of communities.

This idea lacks concrete archaeological evidence—no physical artifacts related to navigation have been found—but is supported by oral traditions of the Tlingit and Haida tribes of Alaska, “who maintain that their ancestors were a seafaring people who have lived in this region since the dawn of history,” Raff writes in *Origin*. The oral traditions of the Tlingit are rich in narratives of ancestors traveling along the Pacific Northwest Coast and down the Stikine River, over and below glaciers, foraging for seals and other marine mammals.

In 2007, a genetic reconstruction of the genome of Shuká Káa, a man whose skeleton was found in an Alaskan cave and was dated to 10,000 years ago, added credibility to the kelp highway theory. It showed that Shuká Káa's people were the ancestors of the Tlingit. At the same time, chemical analysis of his teeth showed that Shuká Káa had indeed grown up on a diet of seafood. Other archaeological artifacts found alongside his body in the cave suggested that he had engaged in long-distance trade for high-quality stone, adding further support to the coastal highway theory. The genetic sequencing work was done in consultation with the Tlingit tribe, and after the work was completed, Shuká Káa was buried in 2008.

Raff reminds her readers that not all Native American origin stories align neatly with the results of genetics. And that genetic results are not set in stone, as new techniques overturn initial interpretations. In the closing pages of *Origin*, Raff calls it hubris to think a definitive history of the peopling of the Americas is possible.

RAFF VENTURED INTO WRITING for the public in 2015 when she created a blog called Violent Metaphors. The name, suggested by a publicist friend,

I don't want to be this white savior liberal girl running around.

reflected her feisty feelings at the time. “I wanted to go after pseudoscience and the anti-vaccine stuff that really made me mad,” she said. One post about misinformation about measles’ vaccinations begins, “Dear parents, you are being lied to.” “I learned the things that went viral were the ones that I was writing passionately about,” Raff said. “When I had a real connection, emotional connection to a topic, I wrote the best.”

Raff’s blogging landed her in the culture wars, where she became a target for those who saw her as an embodiment of political correctness over objective science. In particular, Raff has been in the crosshairs of Elizabeth Weiss. Weiss is a professor emeritus of anthropology at San Jose State University and the coauthor with James W. Springer of *Repatriation and Erasing the Past*. Weiss and Springer criticize NAGPRA and the reburial of human remains in ancestral burial grounds. They argue “secular and scientific scholarship concerning human and biological differences” is being suppressed and censored by deference to Native American religious myths.

In a 2022 review of *Origin* in the online magazine *Quillette*, Weiss aimed that criticism at Raff.

“To defer to Indigenous creationist ideas is no different, in principle, from deferring to religious Christian attitudes,” Weiss wrote. As “an anthropologist, I find the anti-scientific trend that the book represents to be deeply unsettling.”

In response, Raff said, “Being respectful of the beliefs and priorities of Indigenous peoples is not in opposition to science, and I’ve never been asked by any tribe to change the results of our research to fit an agenda. Weiss is stereotyping Native Americans as anti-science, which is ludicrous; they are as varied in their perspectives and belief systems as all people are.”

Raff was born Jennifer Anne Kedzie in Carbondale, Illinois, the first daughter of three. Her youngest sister died in infancy of spinal muscular atrophy, a rare genetic disorder for which there was no cure in the early 1980s. Raff was 4. After the loss of her daughter, Raff’s mother was moved to return to higher education and neuroscience, and the family lived in university towns in Missouri and Indiana. Raff’s parents divorced amid the moves and financial struggles, but Raff stayed close with both her parents. Raff’s father worked as a quality assurance engineer in industry, and she credits him

for pushing her to look for answers and research. “Every time I would ask him a question, he would be like, ‘Look it up.’”

On the campus of Indiana University where she lived as a student, Raff grew close to Elizabeth and Rudolf Raff, both biology professors. Rudolf Raff was a pioneer of evolutionary developmental biology and director of the Indiana Molecular Biology Institute. Their son, Aaron, was Jennifer’s boyfriend, and Aaron and Jennifer married while she was in college but divorced during her last year of graduate school. “It was horrible, a really hard time,” Raff said. “But I got through it. I focused on martial arts and fighting. I thought, ‘This could be a life for me.’ And then I thought, ‘No, you know what? I love science more.’” She kept Raff as her surname.

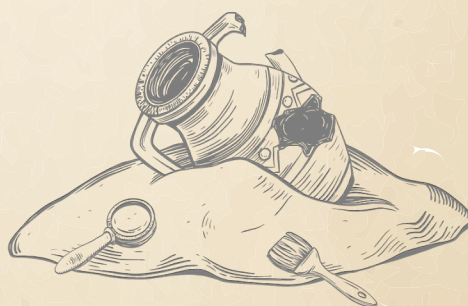
Raff has never lived outside the inland heart of the country—Illinois, Indiana, Utah, Texas, and now Kansas. Raff’s home is decorated with objects embedded with personal meaning—sepia photographs of her family, traditional weapons used in martial arts, and a handful of paintings. *Low Tide*, a peaceful landscape work by the Native American artist Linda Infante Lyons, hangs above the dining room table. It is also on the cover of *Origin*. A violent depiction of abolitionist John Brown leading a bloody uprising against enslavers in 1865 hangs in the living room.

In the time I spent with Raff, there was only one instance I saw her look incredibly uncomfortable. It came during a dinner at her home with her husband, Colin McRoberts, a lawyer and negotiations consultant; their son, Oliver; her mother, Kathy; and a friend of Raff’s, Peter Koenig. As we discussed the success of *Origin* and Raff’s advocacy for the inclusions of Native Americans’ own stories in archaeology, Koenig remarked, “It took a white girl for Americans to hear the story.” Raff buried her head in her hands and hoodie.

“I don’t want to be this white savior liberal girl running around,” Raff told me later. “I think I have a platform. I don’t know if it’s because I’m white, because I’m a professor, because I’ve been writing for the public for a long time. I don’t know. It might be all these things.”

In the spring of 2024, Raff received a Guggenheim Fellowship to complete her second book, *The Ancients: The Untold Story of How We Became Human*. “It will continue my focus on challenging pernicious concepts of biological race and colonialist practices—particularly those still prevalent in paleo-anthropology and paleogenomics,” Raff said. It will continue her quest to “complicate” the picture of human origins, so the public can begin to see the complex narratives of belonging. Where an origin is not a single point on a distant horizon, but a forest of interwoven roots. ☺

ELENA KAZAMIA is a science writer from Greece. She has a master’s degree in conservation from University College London and a Ph.D. in plant sciences from the University of Cambridge in the U.K.



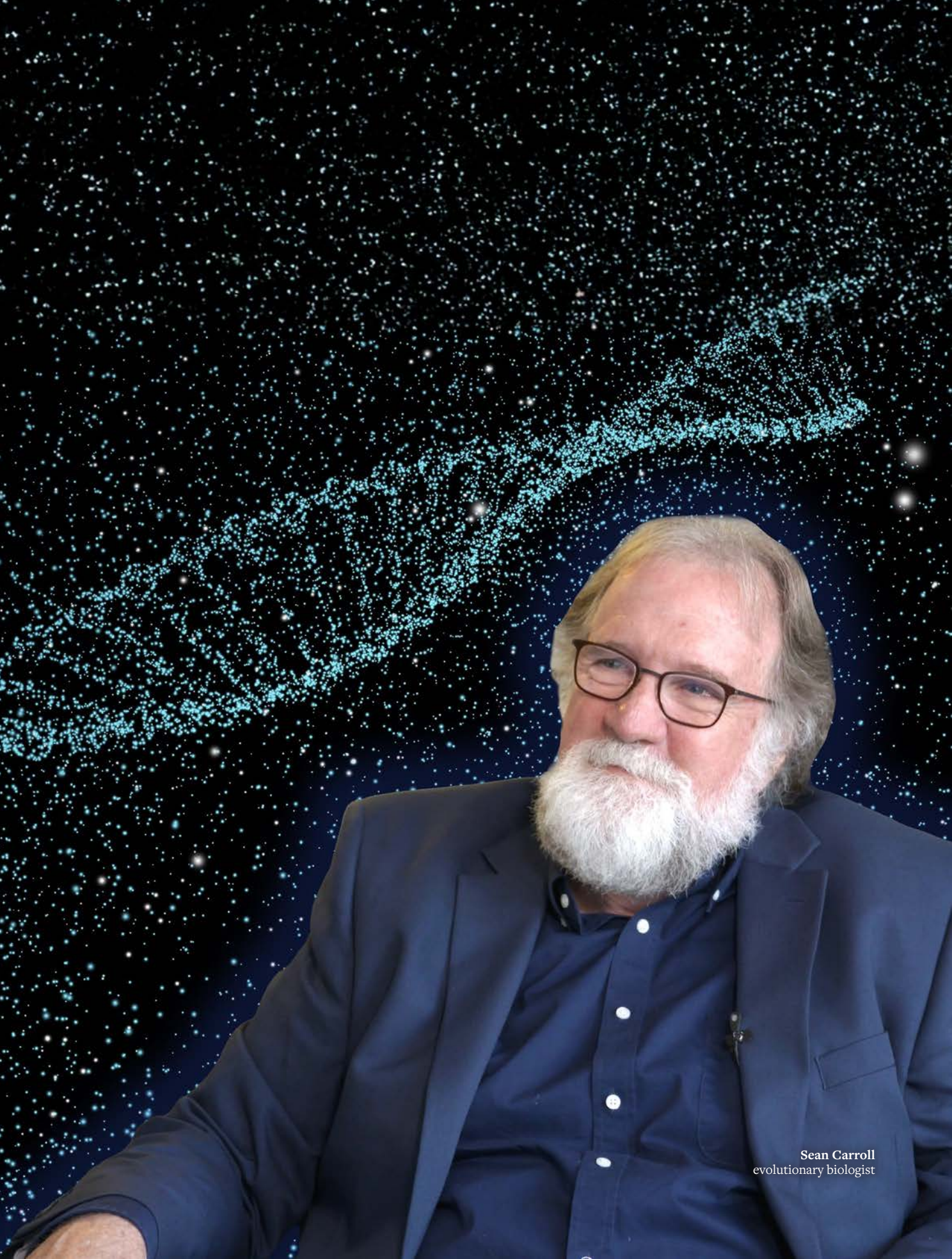
The Sean Carrolls Explain the Universe

*Why are we here? Is there life on other planets?
The renowned scientists who share a name share
their answers to life's big questions.*

BY JOHN STEELE



Sean Carroll
physicist



Sean Carroll
evolutionary biologist

T HIS IS THE TALE of two Sean Carrolls. *Nautilus* brought the two scientists together for the fun reason they share a name. And their conversation is filled with humor and camaraderie. And brilliance. The Sean Carrolls bring their perspectives from physics and evolutionary biology to bear on timeless questions about the origin of life, the possibilities of life on other planets, the tension between science and religion, the fate of Earth, and how they first got enchanted by science as kids.

Sean Carroll, the evolutionary biologist, is the former vice president for science education at the Howard Hughes Medical Institute, where he championed research and the role of science as a human endeavor rich with drama and beauty. His books include *A Series of Fortunate Events* about the chance occurrences that shaped life on Earth and *The Serengeti Rules*, which traces the invisible rules that govern ecosystems. His writing is rich in personal narratives that uncover the mechanisms of biological order and collapse.

Sean Carroll, the physicist, is a distinguished theoretical physicist celebrated for his contributions to quantum mechanics, cosmology, and the philosophy of science. He holds the position of Homewood Professor of Natural Philosophy at Johns Hopkins University. His most recent books are part of a series, *The Biggest Ideas in the Universe*, in which he brings readers “up to speed with exactly what professional physicists are talking about, with an emphasis on established knowledge rather than speculation.” His other books include *From Eternity to Here*, which explores the concept of time; *The Big Picture*, discussing the origins of life and the universe; and *Something Deeply Hidden*, focusing on quantum mechanics.

As the two Sean Carrolls sat down together in a conference room at the Howard Hughes Medical Institute in Maryland, the first thing they had to talk about was mistaken identity.

Sean Carroll, physicist

It’s so good to talk to you in person. I’ll start with my little story. When I was in graduate school, still in that

early stage of your scientific career—who knows where you’re going?—I was walking down Harvard Square by the magazines, and *Time* magazine was coming out with an issue with 40 scientists under 40 who are going to change the world. And jokingly I said to myself, “Oh, I bet I’m in there.” So I pick it up and I’m in there! There’s my name. But I realized they made a terrible mistake. They had the wrong Sean Carroll. This guy was doing evolutionary biology, not cosmology at all. And that’s when I realized there was another Sean Carroll lurking out there in nature.

Sean Carroll, evolutionary biologist

And the confusion persists. The most common is when I’m giving a talk on a campus and the poster for the talk is illustrated with your books. People bring me your books to sign and I explain the confusion and they’re like, “Will you sign it anyway?” I say, “Maybe you can get both of us to sign it.”

Sean Carroll, physicist

The only one that hurt was when I was invited to a ritzy conference in the hills of Tuscany at a villa. I accepted and they said, “Actually, we don’t want you. We’re looking for the other one.”

Sean Carroll, evolutionary biologist

They didn’t find me, because I would have gone!

Sean Carroll, physicist

So, what happened to make you do biology? It’s so messy and hard.

Sean Carroll, evolutionary biologist

It's funny. I had decent math ability as a kid. But my math ardor waned as I got into high school. That probably had something to do with how things were being taught. It just got less interesting, less fun. At the same time, friends in my neighborhood introduced me to flipping over logs and things like that, up by Lake Erie. Catching snakes and salamanders and frogs was something I did nearly every day. I thought "maybe I'll be a herpetologist." How did you stay on your path? How old were you when you knew you were interested?

Sean Carroll, physicist

I was 10. I was reading books about black holes and the Big Bang. I was never a go-out-there-and-touch-things-in-nature kind of guy. Even when I became interested in cosmology, my parents would get me a telescope or take me to the observatory and I'm like, "Why are we here? What is this? I can just read about this in a book." It's the simplicity and profoundness, the fact that the world that physics explains to us is so different than our expectations, and yet our minds can wrap around it a little bit. That's what really got me excited.

Sean Carroll, evolutionary biologist

So, were you explaining things around the dinner table?

Sean Carroll, physicist

I was excited but I grew up in a resolutely non-excited family. No academic background, no bookshelves in our house. My parents were very supportive, but they had no idea what I was interested in or what I was doing, even in my science classes. I remember very vividly my high school teacher asking us all what we wanted to do, and I said I wanted to be a theoretical astrophysicist. He was so aghast that he wrote the words "theoretical astrophysicist" on the board, just to show everyone how weird that was. What was your background?

Sean Carroll, evolutionary biologist

My dad grew up on a farm, but he ended up being a scholar in Gregorian chant—the lucrative field of Gregorian chant. The example he set was that he followed his passion.

I'm a super-duper atheist, but I don't think we can figure out our purpose just from doing science.

Sean Carroll, physicist

Were you religious in that sense? Or was it more about the songs?

Sean Carroll, evolutionary biologist

My dad was scholarly and knew a lot of languages. He read widely and his ideas didn't conform to the party line, although he was a very observant Catholic. When the time came and I didn't have those feelings and thoughts and sentiments, all he asked of me was that I would watch his choirs perform at Christmas. I said, "Dad, I'd be happy to come listen to the choirs at Christmas." So, I was released of my religious duties at age 12.

Sean Carroll, physicist

It's a complicated relationship between science and religion. I have good friends in cosmology and biology who are also deep believers. Do you think they're fooling themselves? Do you think there is really a controversy there?

Sean Carroll, evolutionary biologist

The evolutionary biologists I know are predominantly nonbelievers. We like science as an explanation of things, and those other explanations that we may have grown up with don't carry much power. My dad was pro-science, but he was also strongly a person of faith, so clearly those ideas can coexist in people and probably coexist in a significant fraction of people in the country or in the world. They accept the findings of science, but they have strong religious faith. If you're talking about somebody who's a pure creationist and doesn't want to engage with science, that's not interesting, and neither are scientists who say that science is all there is.



WORLDS BY THE THOUSANDS

“Back when you and I were graduate students, we had the solar system,” Sean Carroll, the physicist, tells Sean Carroll, the biologist. “Now we have thousands of exoplanet systems. I’m not at all surprised.”

Sean Carroll, physicist

Religion was never meant to be just a statement about how the world works, but there are statements about how the world works in it. Those are the ones undermined by the success of science. But there are the other parts of religion, the social parts, the moral parts, the purpose of life, the meaning of things. Why do human beings exist? What is our purpose? Why are we even in this game to begin with? Maybe science can help us figure it out. But I would be on the side that says we have not yet figured it out. Do you see that as a challenge we haven’t yet risen to yet?

Sean Carroll, evolutionary biologist

I think you may be shocked by who I quote here, but I’d love to know what the pope says.

Sean Carroll, physicist

Let me hereby extend an invitation to the pope to come onto my podcast, Mindscape, or to come to *Nautilus*.

Sean Carroll, evolutionary biologist

The pope has said some powerful, eloquent things about why we’re here with respect to our common home, the planet. I think these are such welcome thoughts to a scientific community that’s

so concerned about the dual crises of biodiversity loss and climate change. The pope is asking questions like, “What’s the meaning of our journey here on Earth if we’re going to leave it a shambles?” Getting into that realm of meaning and purpose and accepting that billions of people are influenced by faith, and influenced by faith leaders, is where the science world has to build bridges and say, “We have a common cause. The common cause is care for our common home.”

Sean Carroll, physicist

I’m as atheist as they come, super-duper atheist, but I don’t think we can derive “ought from is,” as David Hume taught us, or figure out our purpose just from doing science. In *The Big Picture*, I explained that, for thousands of years, the best human minds who cared about how we should live, and why we’re here, were doing so in the context of a religious tradition. It would be weird if they didn’t say anything interesting or important. I think a lot of scientists, especially the ones who are so enthusiastically atheist, don’t want to give any credit at all to that kind of thinking, and they probably exaggerate the extent to which religious people, as you say, also really believe all this stuff.

Sean Carroll, evolutionary biologist

I’m just as atheist as you. I don’t have a fiber of belief in my body. But on campuses, students want to engage with us. They don’t want to hear the most orthodox view from an evolutionary biologist or cosmologist and say, “This is it. That’s all there is. This is the law.” And they don’t want somebody in a collar to step up and say, “No, you’ve got to believe this as we put it down.” When kids start getting exposure to nuance, the richness of ideas, people with complex thoughts, then the windows open, and it’s a healthier journey from there.

Sean Carroll, physicist

One of the things I love about science is that it leads you to believe things whether you like it or not. At some point, you can’t escape. You’ve given a pitch, for example, for the importance of randomness and contingency in evolution and history.

Sean Carroll, evolutionary biologist

In my book *A Series of Fortunate Events*, I’m focused on the asteroid impact of 66 million years ago. It was the biggest rock to hit the Earth or the moon probably in the last half billion years, and where it hit mattered. If it hit most other places on Earth, it probably would not have triggered a mass extinction. When you think about that, you think, “Wow, but for one rock hitting the Earth 66 million years ago in a different place, humanity doesn’t exist.” So, I’m not a replay-the-tape sort of guy. I think there’s too many one-offs that easily could’ve gone another way.

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Sean Carroll, physicist

If you do replay it from 5 billion years ago, where are the bottlenecks? Do you think the initial existence of life was difficult? Do you think that multicellular life was difficult?

Sean Carroll, evolutionary biologist

Oh, this is a fun one, yeah. My sense, and I think it's shared by a pretty good part of the biological community, is that simple, unicellular, microbial life might be fairly prevalent in the universe. I'm of the view, just on the balance of evidence that, Yes, while life took a little while to get cooking, I don't think it was that hard. With the dynamic geology and the chemistry of the Earth, and that whatever gave us water, collision of the comet, whatever, to put all the water here. You must know these theories.

Sean Carroll, physicist

I want to push back a little. That's telling the story from a slightly parochial perspective. We know that Earth did it in the last 4 billion years of evolution. A lot of contingent events needed for it to happen that way. Are there completely different ways to get big animals with big brains?

Sean Carroll, evolutionary biologist

We have lots of life forms that persist, and there's tremendous diversity among microbial life, so I don't think any large stuff is going to be easy. If you gave me 100 planets with life, I would love that sample. I'm going to think large life like ours might be relatively scarce.

Sean Carroll, physicist

Well, I do know enough to say that there's a lot of planets out there. Back when you and I were graduate students, we had the solar system. Now we have thousands of exoplanet systems. I'm not at all surprised. I think there was some kind of weird PR thing where people were acting surprised that we saw all these planets. I was just expecting most stars to have planets around them. Many of them seem to be perfectly habitable by the little information we have. It's very plausible that life forms on some substantial fraction. Even if it's 0.1 percent, that's still an enormous number of planets that have life on them, and we have not been visited by any aliens.

Just to be very clear, if there is an alien civilization that has technology to build spaceships that go at 0.1 percent the speed of light, they would have filled up the galaxy a long, long time ago. The galaxy's big, but it's also old, and it's easy for any ambitious civilization to go everywhere, and they haven't. The Fermi paradox, right? "Where are they? Why aren't they talking to us?" What's the answer to this?

Sean Carroll, evolutionary biologist

They probably have a weak Congress.

Sean Carroll, physicist

Gridlock, in a filibuster.

Sean Carroll, evolutionary biologist

[Laughs] You have the technology evolving in a culture, and then you have the politics. The technological capability is just outstripping the political ability to deal with it. That's going to be my theory of why they don't get here.

Sean Carroll, physicist

I think the simplest thing is that there's lots of life in the universe, and it's all monocellular, unicellular. We're weird in that we're not.

Sean Carroll, evolutionary biologist

Right. Visit the Earth anytime in the first 4 billion years or so and everything's small. Everything's essentially microbial. That was the state for the longest time. Animals and redwoods are weird. They're the unusual things.

Sean Carroll, physicist

One of the things that I point out as my favorite argument for the existence of God—I think that none of them are any good—but my favorite is that the constants of nature in the universe allowed for the existence of very complex structures such as ourselves. As a physicist, I actually do buy the argument that, provisionally, because we don't know, because there's only one universe that we get to study, but if those constants of nature, the mass of the electron, et cetera, were very different—in some cases just a little bit different, in some cases very different—the energy



of empty space, all sorts of numbers that characterize our universe, it's hard to imagine as much complexity, as much intricacy.

Maybe we just don't know how to say it, but it's easy to imagine a more barren universe. If neutrons were lighter than protons, all the protons in the universe would decay into neutrons. There'd be no atoms, no chemistry, no life. If you think that this was chosen by a designer to allow for our existence, that actually makes a little bit of sense to me.

Where it fails is pointing out that, under theism, if you don't think of the world as perfectly natural, you don't need complex physical structures to have life, because God can make life on rocks. God can make anything be sentient and have a rich environment to live in. Only under naturalism do you need that kind of fine-tuning, that kind of very specific ability to let complexity evolve. Do you have the same or a different take about the fine-tuning of the world in which we live to allow for this kind of wonderful diversity?

Sean Carroll, evolutionary biologist

I'm not an expert. But from a different point of view, I think these kinds of religious ideas were cooked up by humans at a time when they really didn't have a grasp of the world around them. Let's do a thought experiment. Take all those ideas off the planet. Let's start over. Based on what we know from science today, would we have these ideas? I think not. I think we're just dealing with their legacy and not dealing with their strength, their power of explanation relative to what we've learned from science.

MYSTERIOUS NO LONGER "Animal diversity is not as hard to explain today as it was 30 years ago," Sean Carroll the biologist tells Sean Carroll the physicist. "How do you get giraffes and butterflies and earthworms? Well, jeez, it turns out the explanation's a little simpler as we understand cellular machinery and the rise of biological complexity on Earth."

Sean Carroll, physicist

I completely agree. I also don't want to sweep under the rug the profoundness of the unanswered questions that we have. One of them is the development of complex structures in the universe. The universe was very simple near the Big Bang, and it will be simple in the future when we reach heat death and all the stars stop shining. There's this happy middle moment that we're in now, where things can be complicated and intricate and hierarchical.

To me, the most pressing question in science is why did that complexity come to be, and is it special or is it generic? Do you really need to work hard to allow for brains? Brains are hierarchies. They're these networks that are very organized. We see some of the things on the internet or the economy or the biosphere. Is that easy or is that hard? I just don't know.

Sean Carroll, evolutionary biologist

We both see science as a narrative. As storytellers, we're trying to tell you the story of life as accurately and verifiably as we can. And little by little things drop in. Animal diversity is not as hard to explain today as it was 30 years ago. How do you get giraffes and butterflies and earthworms? Well, jeez, it turns out the explanation's a little simpler as we understand cellular machinery and the rise of biological complexity on Earth.

Sean Carroll, physicist

I want to take a slightly left turn here. I was astonished to learn that the size of the human genome, just in number of base pairs, is so much smaller than that of a sunflower. There's a weird mismatch. In some sense, we're more efficient, right? Our genome is doing more with less because we've had some time to evolve. But the development of complexity that we've been talking about is not smooth, right?

Wow, but for one rock hitting the Earth 66 million years ago in a different place, humanity doesn't exist.

Sean Carroll, evolutionary biologist

No, not at all.

Sean Carroll, physicist

You mention storytelling. We're both involved in communicating science to young people enthusiastic about science. We learn as we do it that certain stories resonate with people. When it comes to this kind of sales pitch for making the planet a better place, preserving it, what are the things that people light up about?

Sean Carroll, evolutionary biologist

One thing they need is hope. I think that they're surrounded by a glut of gloom and doom and dysfunction. If you can show them a path to hope, and authentic hope, meaning that there's a genuine reason to be hopeful, and that action can pay off, I think people can get enthused by that and get behind it. And that could be something like missions run by the Jet Propulsion Laboratory. Their motto, "Dare mighty things," has got to be one of the best mottoes of any organization.

Sean Carroll, physicist

I've been on JPL committees. You don't always notice that's the motto.

Sean Carroll, evolutionary biologist

[Laughs] OK. But you see a picture of a rover on Mars and people are excited. Maybe they see a picture of a butterfly or maybe a TikTok of a hummingbird. That lights them up. The more we can offer glimpses into what scientists do, why we do it, and the fruits of our work, we can give people an understanding that is enriching to their lives. It's not just intellectual. The more science can reach people at an emotional level is what's going to be sticky. What do you hope from your audience?

Sean Carroll, physicist

My wife, Jennifer, who's a professional science writer, keeps telling me, "You should mention human beings in your stories." The first volume in my series, *The Biggest Ideas in the Universe*, is about classical physics. So I have to talk about Isaac Newton, the guy who gave us classical physics.

I tell the story that during a plague Newton was hiding away in Cambridge, where he wrote *Principia Mathematica*. Then you take it a little bit more deeply. It was the dawn of the Age of Reason. It was when the Royal Society was founded. The coffee shop was a new technological invention, where people would go and have coffee and talk about ideas.

Robert Hooke of Hooke's law and Christopher Wren, who designed Saint Paul's Cathedral, and Edmond Halley, who discovered the comet, were friends. They were card members of the Royal Society, and they would retire to coffee shops and think about, "How do we explain Kepler's laws? How do we explain why planets go around the sun?" Guess what? They actually knew, or thought they knew, there was something called gravity, the force of gravity, and the fact that it decayed as the inverse square of the difference—the famous inverse-square law—they had a conviction that would explain why the planets move in ellipses, but none of them had the mathematical chops to do it.

They all knew that the guy who did was Isaac Newton. But they were afraid of him because he was very intimidating. Halley was the youngest. They sort of goaded Halley into going up and visiting Newton, and Newton receives him. Halley says, "So, by the way, if we had a gravitational force law that went as the inverse-square, what shape would the planets move in?" Newton's like, "Ellipses." Halley's like, "How do you know that?" Newton's like, "I calculated it." Halley's like, "You should tell us how to do that."

How much physics do you learn from that story? None, or very little. How much insight do you get into how physics is done in the real world? How does physics go from being a once-and-for-all set of equations to this is a human endeavor? These were people with their anxieties and their coffee shops. Hooke and Newton became lifelong enemies. Newton had a lot of lifelong enemies. That's another thing that you learn. Newton was a bitter, terrible person, but that's what scientists are sometimes like.

Anyway, a long-winded answer to say that I give readers different things. I try to put some equations in there. I put some history and stories in there. I try to put some philosophy in there. And do it all at the same time.

Sean Carroll, evolutionary biologist

You told a story right there—that is the tool of engagement.

Sean Carroll, physicist

It's the single most effective one, if you had to pick one.

Sean Carroll, evolutionary biologist

Narrative connects cause and effect. It is a natural way of carrying events over time.

Sean Carroll, physicist

And drama, right? I lived in Los Angeles for a long time and made friends with screenwriters. I went to a friend of mine who is a screenwriter and said, "I read this book by David Mamet, and he said that in every scene, every character should want something." I thought that was genius, and he was like, "This is Screenwriting 101." A story is not a series of things that happened. It's a series of things that are driven to happen by goals and desires.

Which brings up another big science question I would like to someday understand: Why are there goals and desires? Why are we so interested in certain things happening in the future? The laws of physics don't seem to point us in this direction, but biology does, and I'm curious about that.

Sean Carroll, evolutionary biologist

That's a great question. Do you think that is from our awareness of our own mortality?

Sean Carroll, physicist

I think that a lot of it stems from the fact that we can imagine the future. The fact that we can conceptualize different possible futures is a little bit of a difference between us and other species. Other species don't have the anxieties and embarrassment that we do. We can worry about the future in ways that they can't. The flip side of that is we can have goals. We can be JPL. We can land rovers on Mars. But where did that come from? What was the first organism to have a goal, in which that vocabulary is the right way of thinking about it?

Sean Carroll, evolutionary biologist

One of my favorite biologists, François Jacob, said, "The dream of every bacterium is to become two." That's a fundamental truth about life: Everything that life goes through is just a means of making more of itself, right?

Sean Carroll, physicist

So that's just hilariously anthropomorphic because the bacterium does not have a goal. The bacterium does something, but it doesn't conceptualize different future possibilities.

Sean Carroll, evolutionary biologist

No, it does not. But I still like the aphorism.

Sean Carroll, physicist

It's a good quote. I would even go back further in saying, "The purpose of life is an electron finding a place to rest." Albert Szent-Györgyi said that. It's just we're out of equilibrium. We're eating our food in fuel. We're making more entropy in the universe. That's what we're all here for.

Sean Carroll, evolutionary biologist

Since we've been talking about complexity, we're having a better conversation about it than we could have when you and I were in graduate school. And we'll have a better conversation about it 20 years from now.

Sean Carroll, physicist

I'll put it on my calendar. ☺

JOHN STEELE is the publisher and editorial director of *Nautilus*.

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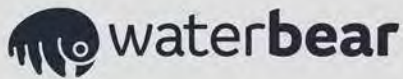
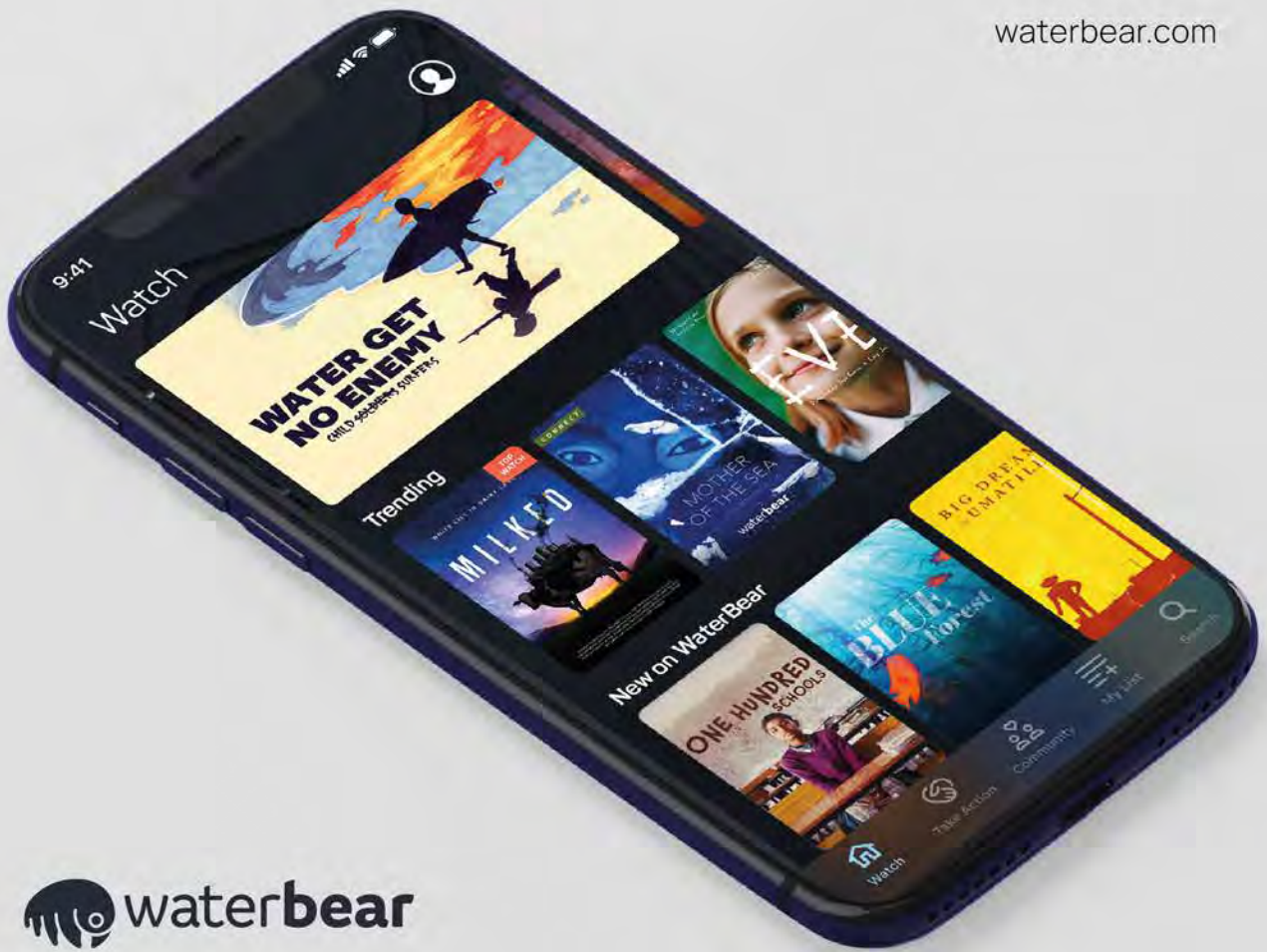
M A G A Z I N E

Findings

A mother is 4.6 percent more likely to give birth in the same month she was born.  Half of all beef consumed in the United States is eaten by 12 percent of adults.  The playing speed of a metal guitarist directly correlates with his intrasexual competitiveness but not his mating success.  Scientists advised against consuming hypersexual zombie cicadas infected with psychoactive fungus.  A metal scar on the surface of the white dwarf WD0816310 indicated that it has cannibalized other bodies in its orbit.  Dwarf rock-wallabies were found to have unusually large teeth. "If I were a vegetable," said a skull-shape researcher, "I would not mess with a pygmy rock-wallaby." 

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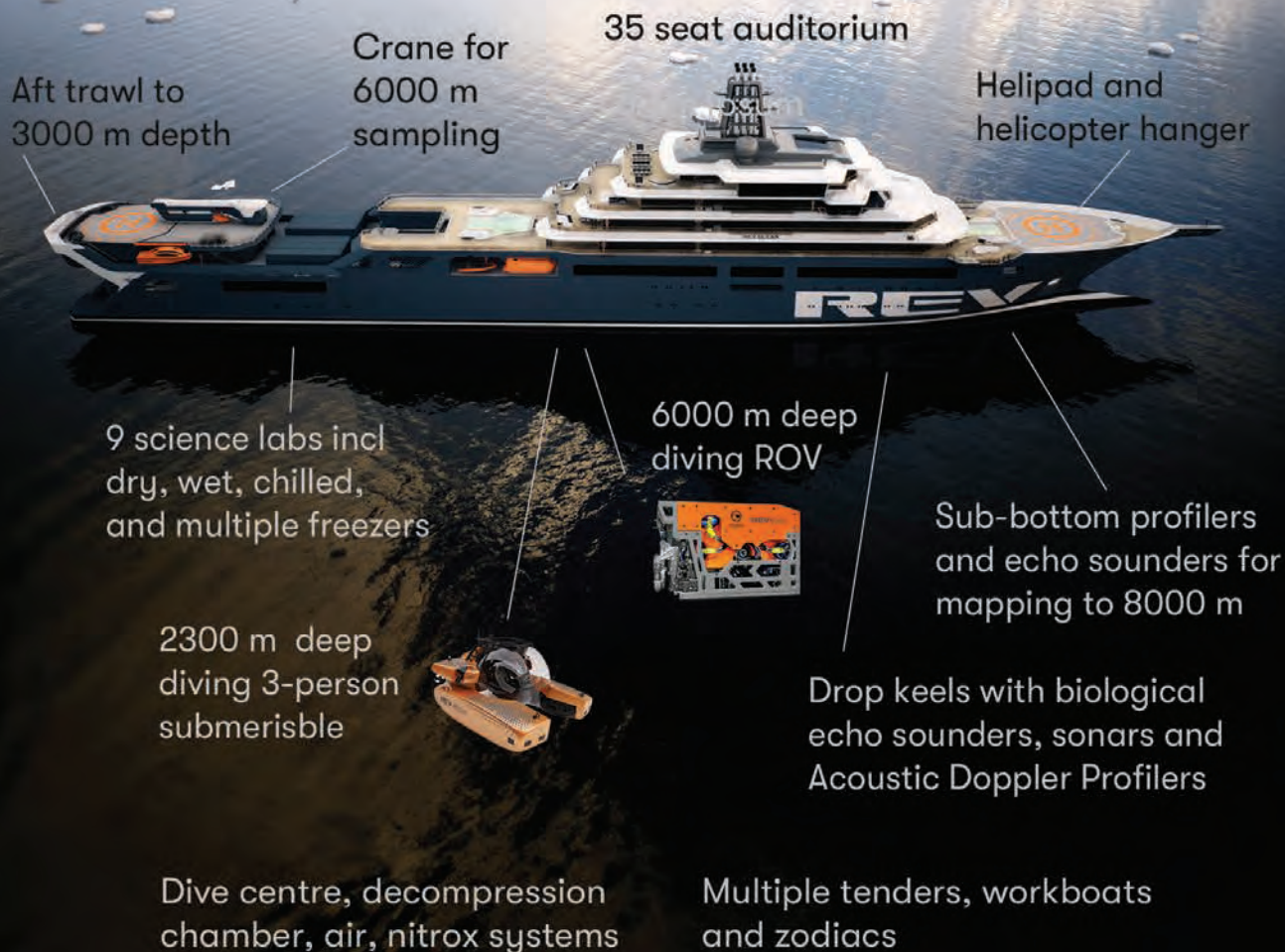
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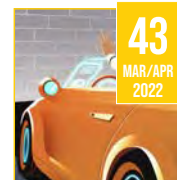
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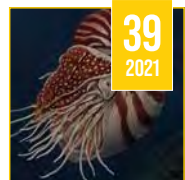
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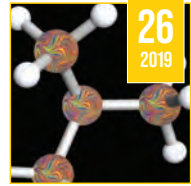
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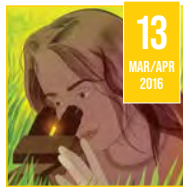
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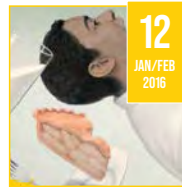
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Jonathan Silvertown

*The author of *Selfish Genes* to *Social Beings* on kinship*

INTERVIEW BY KATARINA ZIMMER

COOPERATION WAS CENTRAL TO THE EVOLUTION OF LIFE

Cooperation must have occurred at the very origin of life, in an abiotic soup of molecules. Life emerged with the first molecule able to self-replicate. Whatever that molecule was, replication would have required two copies, one to act as a template and the other to catalyze the reaction. So cooperation started with the birth of life itself. There could have been no beginning without molecular cooperation.

EVEN GENES COOPERATE

People think it's either all selfish genes or that genes don't matter. But these are two extreme positions. And the fascinating thing is that, actually, genes team up. Genes need each other. We have 25,000 functional genes, but none of these can replicate unless they get into the gametes—eggs and sperm—and you can only make gametes if you have a body. So, genes have to cooperate in order to replicate. You could actually call the cooperation of genes the ultimate example of the advantages of division of labor, because different genes do different things, and you need all those things to make a cell, different cell types, and so on.

KINSHIP ISN'T EVERYTHING

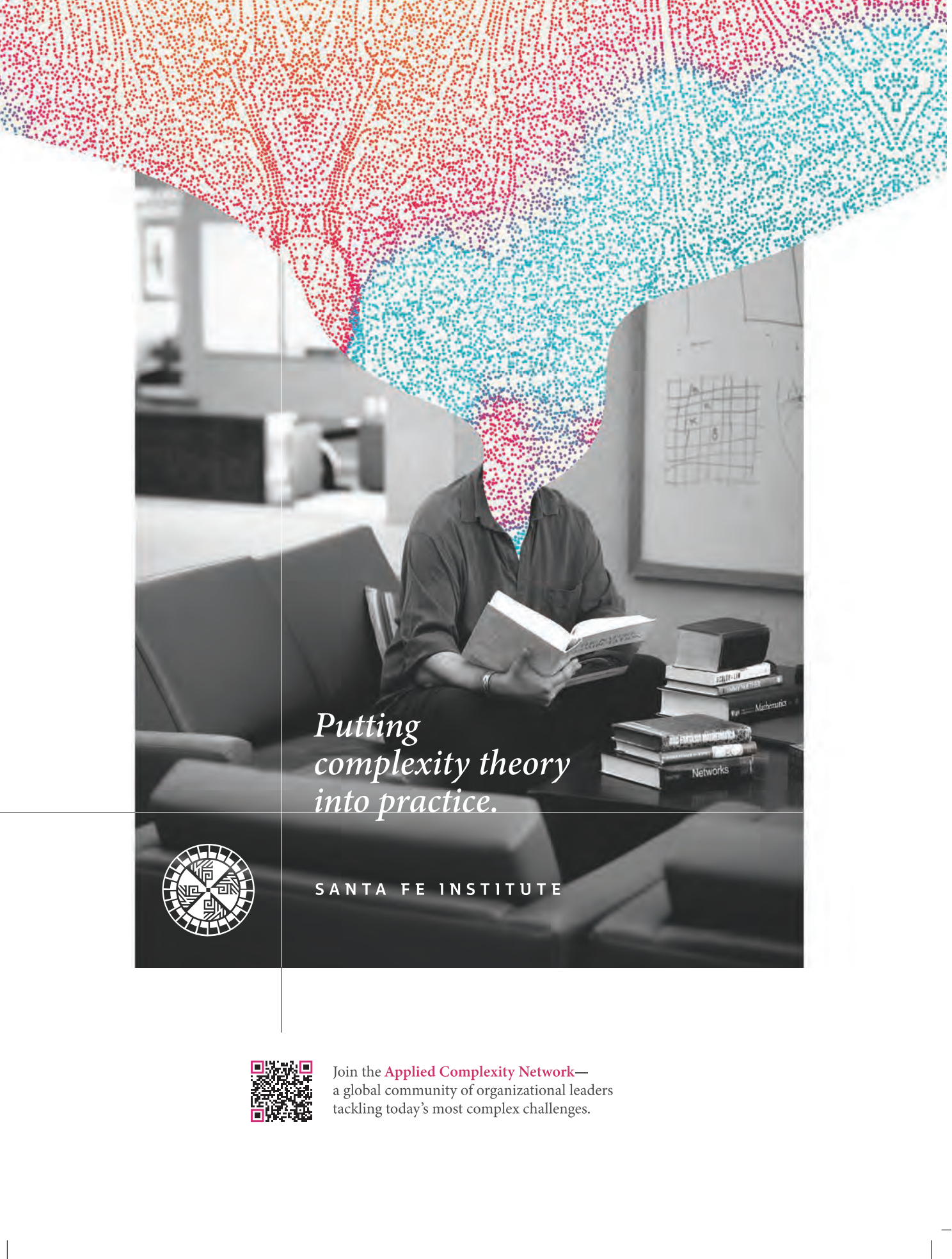
Hamilton's rule says that you do something that benefits another individual if the benefits to you exceed the cost. So why do we help relatives? Because the cost of helping a relative is discounted by the fact that our relatives

carry some proportion of our genes. A famous example was given by British geneticist J.B.S. Haldane, who joked that he was prepared to die for two brothers or eight cousins. Why? If each full sibling carries half your genes, then two of them carry the same number of copies of genes as you've got. If you go to a more distant relationship with cousins, they've each got copies of an eighth of your genes, so you need to save the lives of eight of them to benefit. It was expressed as a joke, but it expressed the logic of kin selection.

Of course, we also cooperate with non-kin. It happens all the time in all spheres of life. So, kinship isn't everything. You find that teams have two advantages over singletons, whether that's people, individuals of another species, or single molecules. The first is the advantage of numbers: A million ants can do a lot more as a group than as a million individual ants. The second thing that makes them successful is division of labor, which is why there are castes in social insect societies.

We are highly cooperative, but I think that we underestimate just how fundamental this is. During World War I there were spontaneous truces between troops from the Allied forces on the one side and Germany and its allies on the other side. One of the most famous examples took place at Christmas in 1914 when soldiers climbed out of their trenches to fraternize in no-man's land. It is amazing how cooperation continually emerges, even in the most unpromising circumstances. ☺





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