NAUTILUS

Man Finds Stick

HOW HUMAN CRAFT BEGAN p.22

ISSUE 24 Science Connected **NAUTIL.US**

MP Neuro

BRAIN DISORDERS AND INJURY | COGNITION | DEVELOPMENT

INTEGRATIVE PHYSIOLOGY AND BEHAVIOR | MOTIVATION AND EMOTION

MOTOR SYSTEMS | NEURAL EXCITABILITY, SYNAPSES, AND GLIA

SENSORY SYSTEMS | TECHNIQUES

The Max Planck Society brings together hundreds of neuroscience researchers, equipping them with the best tools and resources to explore some of the most complex issues facing all facets of brain science.

This collective knowledge and expertise promotes creative, interdisciplinary approaches, allowing Max Planck scientists to make significant advances in the field and develop innovative technologies and techniques to advance neuroscience research across the globe.

Come see and share the future of neuroscience at

MaxPlanckNeuroscience.org

They Grow Up So Slow

THIS ISSUE'S COVER STORY has a simple thesis: Human craft, the building of things by hand, began with the wooden stick. This simplest and earliest act of construction changed the course of human evolution, the first in a succession of tools that would go on to reshape our habitats, diets, and bodies. The story's author, archaeologist Alexander Langlands, paints a picture of an engineering revolution that is laughably simple, profound in its implications—and, crucially, slow.

It's a remarkable fact that we took hundreds of thousands of years to move from a hand axe to a hafted arrow. Over that time, as hides were made into vestments and carcasses into meals, hominids slowly changed with their new tool. The lowly stick waited for us. It did not follow Moore's Law. It did not double in effectiveness every two years. It did not evolve at speeds greatly in excess of the speed of human evolution. It was slow tech.

Today, we confront a very different animal. From suburbs to smartphones, fast tech is creating epochal changes in our way of life without allowing actual epochs of time in which to adjust. That means we are conducting experiments on ourselves, some of which offer financial profit for negative outcomes like social media addiction and fractured attention spans.

Logically, we have three choices. Given a constant rate of human evolution, and an exponential rate of technological evolution, we can continue to run experiments with an ever-greater risk profile; we can seek to constrain our new tools until we have understood and adopted to them properly; or—as Elon Musk has famously argued—we can join our technology instead of trying to beat it. Through even more technology, like neural-computer interfaces, we can merge ourselves with our instruments and hitch our rates of evolution together.

So which would you pick—nostalgia for the stick, or eagerness for the cyborg?

Welcome to *Nautilus* print issue 24.

—Michael Segal
Editor in Chief

Experience the power of poetry

POETRY INAMERICA

Watch the series now on PBS or stream at poetryinamerica.org

Enroll in Fall 2018 courses at poetryinamerica.org/courses

Contents

Preludes

Cover Story

COVER Giulio Bonasera
BACK COVER Francesco Izzo

Themes

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

FRANCESCO IZZO; BILLIONS PHOTOS; GTS / SHUTTERSTOCK

56

Perspective

"The fact that feelings motivate the use of knowledge and reason does not make the knowledge and the reason any less truthful or valid."

—Antonio Damasio, p.42

VITALIY MATEHA / SHUTTERSTOCK; PIXABAY

57

Communities

"When an AI has chosen its own goals, and then begun to pursue them for their own sake, it will be on the road to making its own fine art."

—Hideki Nakazawa, p.64

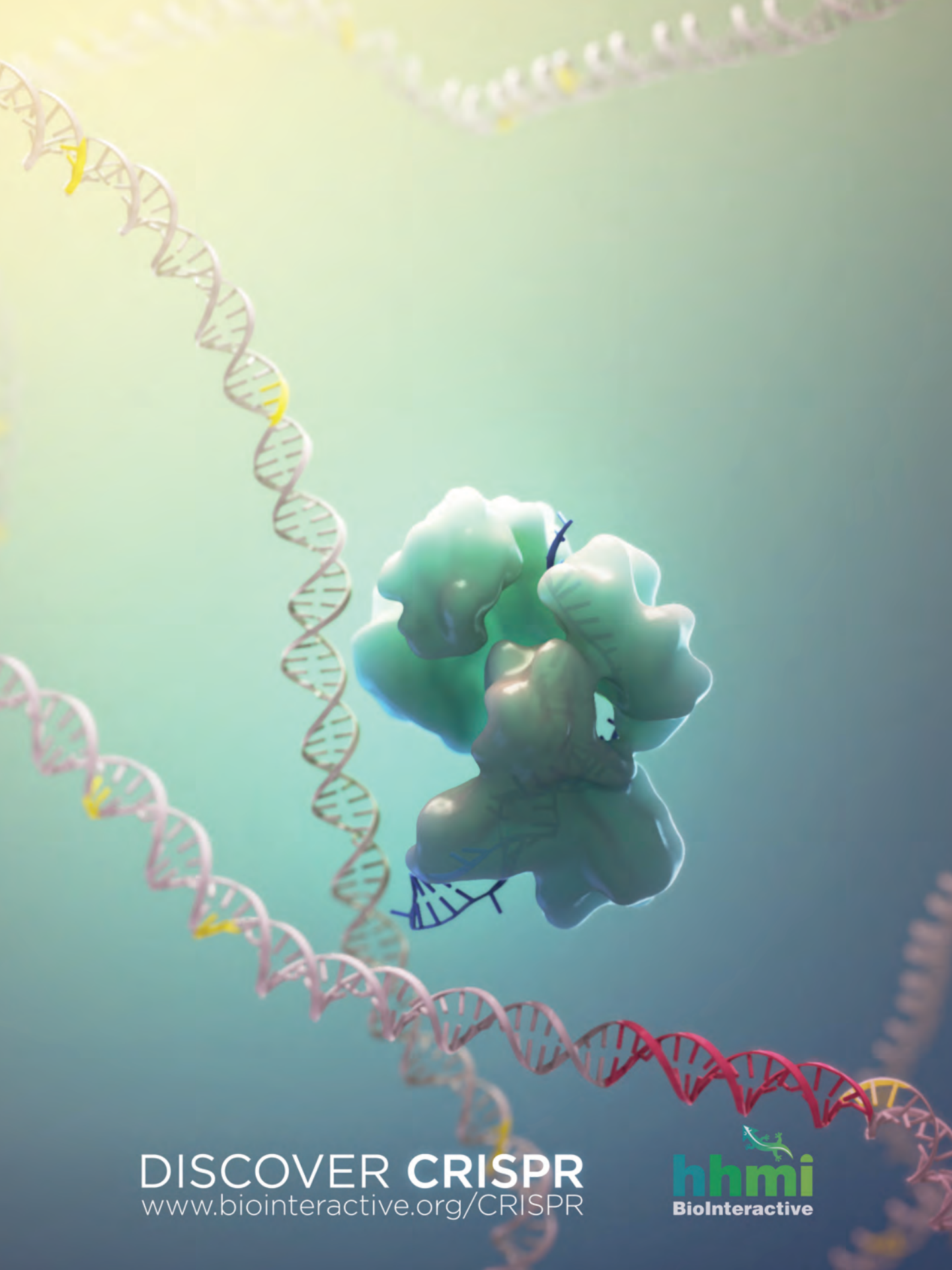
MALTE MUELLE / GETTY IMAGES

58

Self

"I propose that generating humanzees or chimphumans would be not only ethical, but profoundly so."

—David P. Barash, p.78


DISCOVER CRISPR
www.biointeractive.org/CRISPR
hhmi
BioInteractive

NAUTILUS

Published by:

The MIT Press

NAUTILUS *think*

Nautilus has received financial support from:

JOHN TEMPLETON FOUNDATION

SCIENCE Simons Foundation SANDBOX

hhmi Howard Hughes Medical Institute

GLENN FOUNDATION FOR MEDICAL RESEARCH

Olin College of Engineering

Carnegie Corporation of New York

Letters

Reader responses to print issue 23.

"THE RISE AND FALL OF THE ENGLISH SENTENCE"

Excellent article. First, I love and miss the complex and vibrant language. The topic of complexity is interesting and brings the question of the reader or listener's capacity to process. To what extent does systems thinking versus linear come into play? The challenge of linear thinking and processing is that you often need to read the end of the sentence to appreciate the beginning and the journey throughout. Our brains developed to enable survival, not discourse.

—John C. Evelyn

"PHYSICS HAS DEMOTED MASS"

This is the best and clearest exposition I've ever read of the complex process by which quantum interactions lead to the material properties that we directly perceive and interact with. When we peel back the layers of the puzzle, the materiality and mass-ness of the physical world is emptied out. So where does this all leave us? Like peeling back the layers of an onion, when we get done there is nothing but the smell (or, in this case, the color).

—George Gantz

"THE BITCOIN PARADOX"

The fundamental flaw in the "blockchain revolution" is the power requirements of its usage. Bitcoin "mining" is nothing but the conversion of mostly fossil fuels into the binary output of a mathmatical formula. Blockchain technology will never become commonplace as a means of security so long as the power consumption of its usage remains at this level—it is not economically feasible.

—Brian Decker

Super interesting. One question though that may reveal my incomplete understanding: Don't all functioning currencies rely on something like common knowledge? And if so, in what ways is the nature or content of the common knowledge for bitcoin unique?

—msapers81

"THE RESULTING FALLACY IS RUINING YOUR DECISIONS"

People need to be told this? "We lost the game, so we sucked." "We won the game, so we must have played well." No ... there's such a thing as an unjust result. There's no eliminating contingency from life: You can study the racing form all you like, but you can't reliably deduce from this data which horse is going to win the next race. Every step into the future is always a step into the unknown, and the best you can hope to do is align decision-making with likely probabilities.

—Matt Mark

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

CONTACT

25 Broadway, 9th Floor
New York, NY 10004
212 221 3870
info@nautil.us

SUBSCRIPTIONS

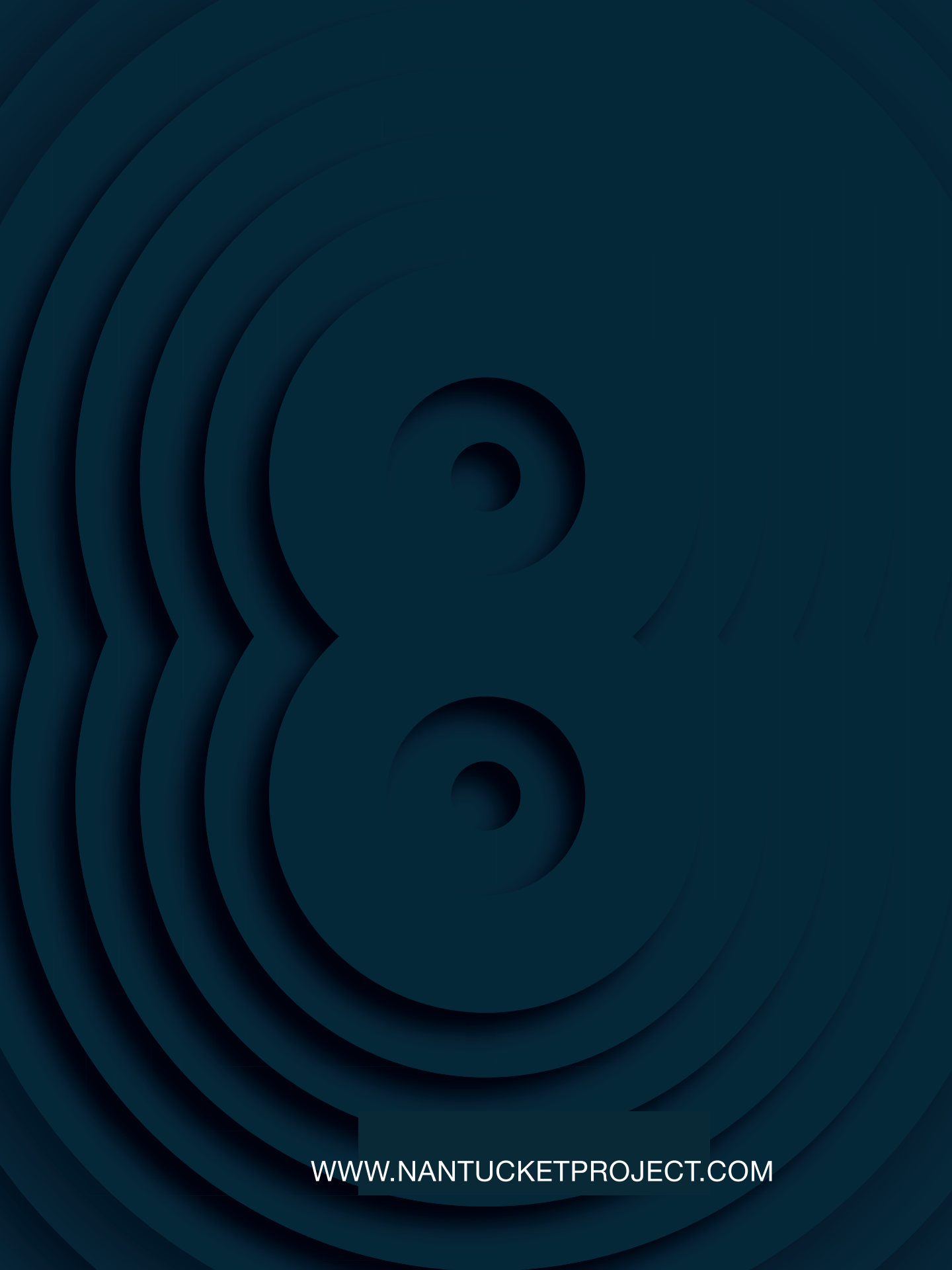
Visit subscribe.nautil.us

the nantucket project

tnp8

September 13–16, 2018
Nantucket, MA

nantucketproject.com/tnp8



WWW.NANTUCKETPROJECT.COM

Preludes

JOE PENNISTON / FLICKR

SOCIOLOGY

Is Facebook Really Scarier Than Google?

MARK ZUCKERBERG, the founder and C.E.O. of Facebook, admitted recently his company knew, in 2015, that the data firm Cambridge Analytica, which assisted with Donald Trump's election campaign, had improperly acquired information on 50 million Facebook users. "This was a breach of trust," Zuckerberg said, in a Facebook post. "We need to fix that."

But that's not the only thing Facebook needs to fix. "The problem with Facebook is not just the loss of your privacy and the fact that it can be used as a totalitarian panopticon," said François Chollet, an artificial intelligence and machine learning software engineer at Google DeepMind, in a tweet. "The more worrying issue, in my opinion, is its use of digital information consumption as a psychological control vector." He elaborated on this point in a thread that's been shared thousands of times. I caught it when global-surveillance critic and *The Intercept* writer Glenn Greenwald quote-retweeted Chollet, calling it a "great thread" on "Facebook's menacing use" of psychology-manipulating A.I. "But remember," Greenwald added, "Google is also a major exploiter of artificial intelligence with very little transparency or public oversight."

Facebook is, in effect, in control of your political beliefs and your worldview.

Chollet bristled at this. "This is the laziest kind of thinking—just because two things share some superficial similarity (they're large tech [companies]) doesn't mean they're equivalent," he said. Why?

Look to the News Feed, Facebook's signature feature, Chollet went on, in this Twitter thread. "If Facebook gets to decide, over the span of many years, which news you will see (real or fake), whose political status updates you'll see, and who will see yours, then Facebook is, in effect, in control of your political beliefs and your worldview."

Fil Menczer, a professor of informatics and computer science at Indiana University, told *Nautilus* that the algorithms used on social media platforms bias our decision-making in ways that exploit our socio-cognitive biases—but search engines aren't entirely innocent.

"The algorithmic biases feed into social and cognitive biases, which in turn feed into the algorithmic biases. Before, people were looking at the evening news on TV, or reading the local paper. But the fact that the medium has changed to online social networks, where you shape the sources of information to which you are exposed, now means that you become even more vulnerable," he said. "Search engines and social media try to predict what content may be most engaging for someone. Ranking algorithms use popularity as one of the ingredients in their formulas. That means that the more people in your group interact or engage with a piece of fake news, the more likely you are to see it."

For Chollet, the sort of danger Facebook poses is unique. "There's only one company where the product is an opaque algorithmic newsfeed, that has been running large-scale mood/opinion manipulation experiments, that is neck-deep in an election manipulation scandal, that has shown time and time again to have morally bankrupt leadership. Essentially nothing about the threat described applies to Google. Nor Amazon. Nor Apple. It could apply to Twitter, in principle, but in practice it almost entirely doesn't," he said. What seems to clinch it for him is that Facebook is ambitiously pursuing advances in AI. "Personally, it really scares me. If you work in AI, please don't help them. Don't play their game. Don't participate in their research ecosystem. Please show some conscience."

If Zuckerberg is morally bankrupt, he's trying to hide it. On Facebook, he announced several changes that will, supposedly, rectify what went wrong with the Cambridge Analytica data-breach scandal. "I started Facebook," he wrote, "and at the end of the day I'm responsible for what happens on our platform."

This is worth keeping in mind, though: That, also at the end of the day, "The motivation for Facebook is not to make you a better person, or even to improve your social group," Simon DeDeo, an assistant professor at Carnegie Mellon University, told *Nautilus*. "It's designed to make money, to show you things you want to see to hopefully induce you to purchase things."

—Brian Gallagher

PSYCHOLOGY

Why Doing Good Makes It Easier to Be Bad

When humans are good, we give ourselves license to be bad.

OSCAR WILDE HAD A GIFT, among other things, for counterintuitive aphorisms. In an 1891 article, he wrote, "Charity creates a multitude of sins."

So perhaps Wilde wouldn't have been surprised by a series of recent scandals in the United Kingdom: The President's Club, an all-male charity which raised money for causes including children's hospitals, was forced to close after the *Financial Times* uncovered sexual assault and misogyny at its annual dinner; executives of Oxfam, a poverty eradication charity, visited prostitutes while delivering aid in earthquake-stricken Haiti; and ex-Save the Children executives Brendan Cox and Justin Forsyth stepped down from their roles at other charities after allegations of sexual harassment and bullying toward junior female colleagues resurfaced.

You might wonder how people who seem so good by occupation could be so bad in private. The theory of moral licensing could help explain why: When humans

are good, it says, we give ourselves license to be bad.

Economists at the University of Chicago reported that working for a socially responsible company motivated employees to act immorally. In one experiment, people were hired to transcribe images of short German texts and paid 10 percent upfront, with the remaining payment delivered if they completed the transcriptions, or declared the documents too illegible to transcribe. When they were told that, for every job completed or marked illegible, 5 percent of their wages would be donated to Unicef's educational programs, the instances of cheating rose by 25 percent. Cheating manifested in both workers not completing jobs (taking the 10 percent upfront fee and running) and also workers saying that documents were too illegible to transcribe (and so receiving the full fee).

"The share of cheaters [was] highest when we frame corporate social responsibility as a prosocial act on behalf of workers," the researchers found. When the workers felt a greater sense that their own actions would lead to charitable donations, like Robin Hood, they in turn felt enough license to essentially steal from their employer to give to charity.

A parallel might be drawn between the transcribers cheating in order to give more money to charity, and the organizers of the male-only dinner hiring hostesses for titillation, to increase the event's appeal and drive up donations. But there are problems with using this theory to explain sexual assault. Moral licensing only applies when the bad behavior can be self-rationalized as good—or, at least, ambiguous.

But generalizing that moral licensing only occurs when bad behavior can be "rationalized" overlooks the nuance of moral license theory, argues Daniel Effron of the London Business School. "There are two versions of moral licensing theory," he says. "One is the 'moral credentials mechanism,' which is more to do with rationalization. Basically it states, 'I've done some good stuff. I've shown that I'm a good enough person. Now I can act ambiguously, because, as a good person, I know that my behavior is more likely to be good than bad.' The other is the 'moral credits' mechanism, which works like a bank account. You do good stuff, you put in a deposit. You do bad stuff, you take a withdrawal. In that case, the bad deeds don't have to be rationalizable."

The latter version explains—but obviously doesn't excuse—the bad actions of Forsyth, Cox, and company. They had built up enough "moral credit" to justify some withdrawals, at least in their minds.

Effron stresses that the "charity sector isn't any more vulnerable" to instances of moral licensing than any other sector. Humans are very good at finding reasons to be bad, he says. "You could make the argument that in the charity sector, you don't have to work as hard to find your moral license for being bad."

—Abbas Panjwani

PSYCHOLOGY

5 Reasons Humans Need Sports

THIS YEAR, an esitmated 103.4 million people—about a third of the United States population—watched the Super Bowl. Devout football fans, and those watching their first N.F.L. game all year, felt the thrill and pull of watching the two playoff finalists, the New England Patriots and Philadelphia Eagles, face off.

Team sports represent, deep in our minds, interpersonal conflict.

Among the two-thirds of Americans who didn't watch, some no doubt wondered what anyone gets out of the spectacle. It's true, in an evolutionarily sense, it may not be obvious what the attraction is: Sports cost time and energy with no clear or direct survival payoff for the players—ditto for the spectators. So what's the point? Well, it's also true, in an evolutionary sense, that sports showcase human nature. Here are five reasons why we watch and play sports.

1. Playing sports prepares us for dealing physically with the world

The importance of being playful is evident in how ancient the behavior is. Humans are not the only animals who play. Birds and other mammals play, and safely learning how to live seems to be play's evolutionary function. Predators play by acting out attacks, pouncing on each other, stalking, wrestling, and softly biting. Ever wonder why your dog likes squeaky chew toys? It sounds like a little animal dying. Prey animals, on the other hand, pretend to evade each other, leaping and running around when they play.

Humans also play to practice things that they need to do to survive—at least in our ancient environment. It's no accident that when we "play" sports, like football, so much of the activity involves running, throwing, aiming, and cooperating. All of these were necessary to hunt on the savannah. Those who played the best probably performed reliably well when it counted.

2. Watching stimulates many of the same parts of our brains as playing

Why would we want to watch—or even pay to watch—someone else playing sports? Because, in our minds, we are playing them. When you watch a quarterback fake out a defender, the motor areas of your brain are active in ways similar to when you are actually doing the activities (the same goes for imagining sports—working out in your mind can make you stronger). We like to watch sports for the same reasons we like to play them.

3. We like drama

Crabs wave their claws around until it's clear who would win the fight, instead of hurting themselves. We can interpret competitive sports as the same kind of symbolic violence and the most popular sports, like soccer, involve the most obvious, pronounced conflict. Team sports represent, deep in our minds, interpersonal conflict. They trigger our sense of loyalty. People align themselves with a team and vicariously feel the joy and sorrow of their team's successes and losses.

4. We enjoy physical excellence

Be it in sports, the arts, or anything else, we are fascinated by a person's or team's prowess. Exactly why is unknown, but we can speculate.

Because our brains react similarly when watching an activity or doing it, perhaps we are subtly learning something about how to do things when watching others.

5. Sports can be beautiful

Lots of people like sports for aesthetic reasons. This is more obvious in sports that are judged, such as figure skating and gymnastics, but even in football, people will describe a "beautiful play." When you ask people why they like sports, they say they watch to get excited, or to calm down, or to get their anger out (which doesn't work).

There's no single answer to why people like sports, just as there is no single reason why people are religious. The attractions of both appear to be a complex combination of different psychological motivations.

—Jim Davies

CE PHOTOGRAPHY / SHUTTERSTOCK

ONE QUESTION

Harvey Whitehouse

How does your identity fuse with a group?

Director of the Institute of Cognitive & Evolutionary Anthropology at the University of Oxford

My first insights into the causes of extreme group bonding came out of my fieldwork in Papua New Guinea. It's when we have a self-defining kind of experience that's shared with the group. One way is to go through very intense rituals. Once you experience something with other people that changes you permanently—you wouldn't be the same person without it—and you believe that other members of your group have gone through the same thing, both the group you're a member of and your personal self become defined by that experience. I later discovered that this creates a fusion between your identity and the group identity. We can measure the level of fusion indirectly, by how people perform on a test of their willingness to suffer for the group, for example. It could be a cold pressor task, where you put your hand into freezing cold water and see how long someone will keep it in there to help or protect the group.

GENETICS

How Your Friends' Genes Affect You

WHAT IF A WOUND, a pierced ear, say, healed at a different rate depending on who was around you? A 2017 study explored this question, albeit with mice. Researchers paired mice together, punched holes in their ears, and tracked the recovery rate. They found that the genome of a cagemate affected how fast the ears healed.

Benjamin Domingue, an assistant professor at the Stanford Graduate School of Education who studies sociogenomics, was fascinated by the "indirect" or "social" genetic effect. He wanted to see if similar things were going on in humans. Through the National Longitudinal Study of Adolescent to Adult Health, a sample of 15,000 Americans who were teenagers in 1994-95, Domingue and his colleagues were able to study the influence of social genetic effects.

We caught up with Domingue to discuss the role social genetic effects play in such findings.

The genotypes of one's social peers are strongly predictive of how far they go in school.

How do social genetic effects operate?

Your heritable behaviors or psychological features may have influences on your friends. These have long been of interest in studies of peer effects. But these studies are hard to get right. However, genes may offer a unique mechanism for studying the degree to which one individual affects another because we know you don't "cause" your friend's genes! That's going to allow us to ask more fine-grain questions.

How do you explain genetic similarity among friends?

What is especially novel about our study is that we have some sense for social context. In particular, we see adolescents embedded in schools. We're finding that social structure is certainly playing a large role. While it is true that friends are genetically similar, it's also the case that schoolmates are genetically similar, and that the genetic similarity among schoolmates is close to genetic similarity among friends. Once you factor in that friends are being selected from within school, a large part of the reason we see genetic similarity between friends seems to be that you're just choosing from an already relatively homogeneous set of schoolmates.

Do social genetic effects have a role in educational attainment?

The individual genome is certainly predictive of how far one goes in school. This is something that has been replicated in other studies. But what we also have is evidence that the genotypes of one's social peers are strongly predictive of how far they go in school as well.

There's a real difference here between, say, height and educational attainment, in terms of how the genetics are working—the genomes of your social peers don't predict your height.

Do your findings hint that nurture influences human behavior more than nature?

I would't put it that way. They're both crucially important processes in understanding human development. Our work allows for both nature and nurture to have influences, which may be intertwined in complicated ways. We're not trying to pick a winner in that fight. I would say that our study has to do with the difference between studies of the individual and studies of social structure, and the degree to which a complete story of human development may require simultaneous analysis of both.

—*Victor Gomes*

DTREN / SHUTTERSTOCK

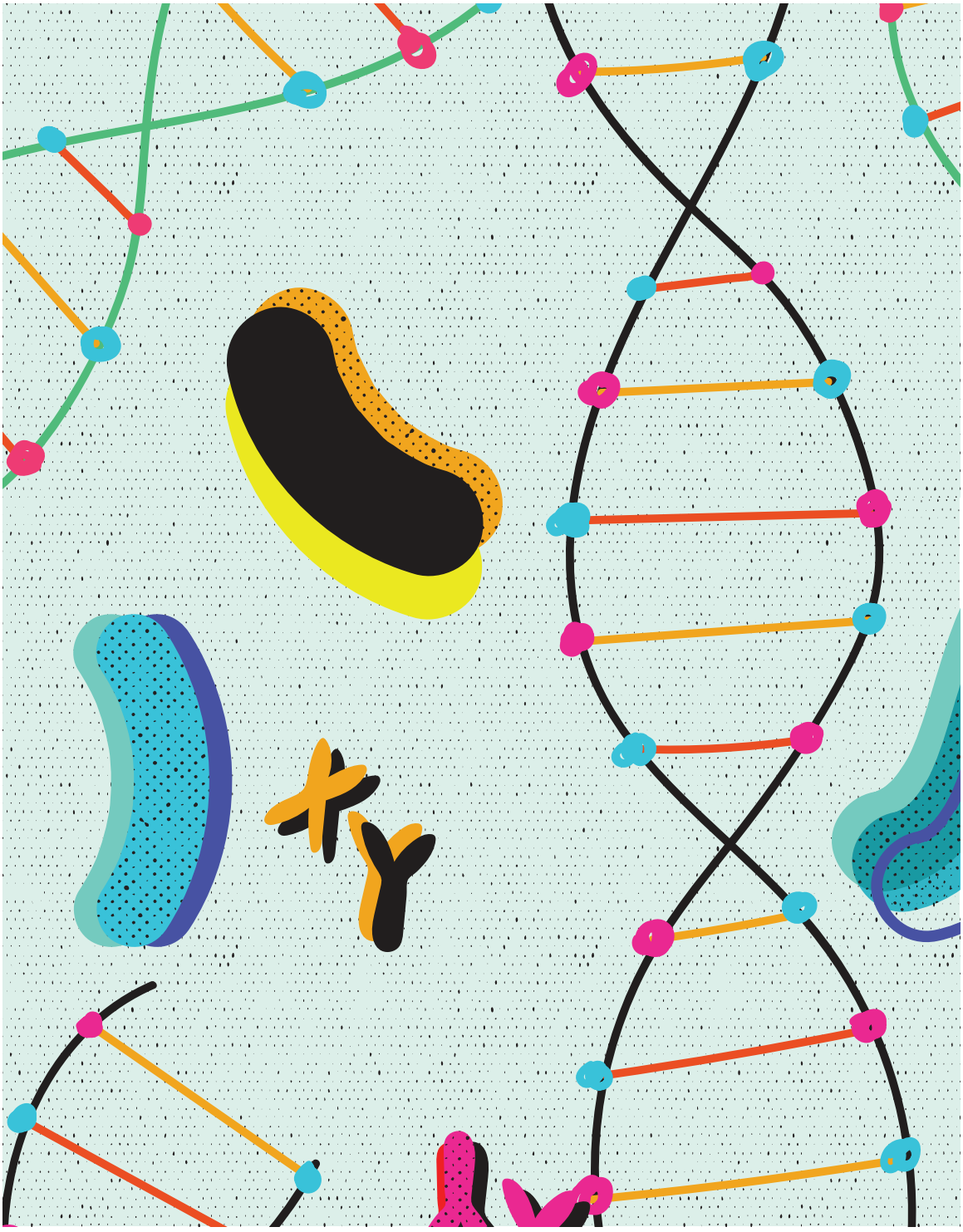


ILLUSTRATION BY **VEDANTI SIKKA**

The Stick Is an Unsung Hero of Human Evolution

Stone's silent sister in the archaeological record

BY ALEXANDER LANGLANDS

IN APRIL 1997, at the snooker world championship held at the Crucible Theatre in Sheffield, Ronnie O'Sullivan stepped up to the table to play a frame in what was expected to be a routine victory in his first-round match against Mick Price. What happened in the next 5 minutes and 20 seconds sent shock waves through the world of snooker and ripples of respect through the wider world of professional sport. To the uninitiated, there is a sequence of 36 balls that must be potted in order to achieve the highest score possible in a frame: 147—what aficionados call a "maximum break." Up until 1997, this had been achieved in official competition snooker on a handful of occasions, in a sport that had effectively turned professional in the late 1960s. It was only a matter of time before the gifted O'Sullivan scored his first competition 147, but it was the manner in which he did it that created such a stir. As he glided around the table he played with a pace and confidence that belied his 21 years. A man at one with the stick in his hands and in a trancelike engagement with his art, he was demonstrably thinking four or five shots ahead and, in playing with such fluidity of movement, O'Sullivan had found a new zone within which the game could be played.

It may seem crude, but to put the achievement into context, it can be compared on pure financial terms with other sports. For a frame that lasted a mere 320 seconds, O'Sullivan was awarded bonus prize money of £165,000. Few can brag that they've ever earned £515.63 per second for the work they do—especially at such a tender age. At its most basic, he makes his money with a length of polished wood and a lump of chalk. For many people, earnings aside, O'Sullivan's feat ranks among the very best

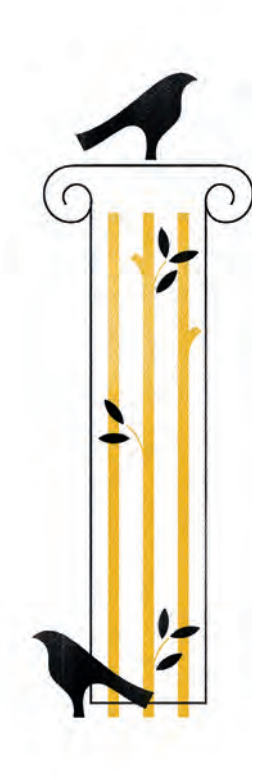
ILLUSTRATIONS BY GIULIO BONASERA

sporting achievements in the world. But for me, it's a celebration of mankind's perfection at stick usage: a poetically beautiful combination of craft, genius, nerve, and swagger.

Sticks are probably where the story of craft begins—the point at which our very distant ancestors progressed from animalistic existences to lives materially enhanced by the objects around them. The transition is most notoriously depicted in the "Dawn of Man" sequence in Stanley Kubrick's *2001: A Space Odyssey* when, in a moment of epiphany, an ape holds aloft the bone he has just used to pulverize to death the leader of a rival tribe before casting it up into the sky. It's unfortunate that my example of humankind's breakthrough moment in the evolution toward tool use occurred in such violent consequences. Kubrick's objective was undoubtedly to comment on what drives technological change, and how using sticks to fight each other was instrumental in the development of human societies. But I suspect they played a more mundane role in our evolutionary journey before they were systematically used for brutalizing fellow members of the species. Even with the orchestral soundtrack provided by the climactic opening bars of Richard Strauss's "*Also sprach Zarathustra*" the sequence would have lacked a certain potency if Kubrick's ape had used a stick to knock an apple off a tree. Whichever way you choose to depict this defining moment in the human story, the successful use of a stick in those primeval times would undoubtedly have brought fame and fortune.

Over 3 million years on, that rule still applies today in many cultural circumstances. Technically speaking, snooker belongs to the world of sport not craft. But looking at sport as an extension of the physical prowess it took to compete—and to be the best—then I have no issue with extending the notion of craft to the work of sportspeople—especially those who employ sticks. Tennis players, cricketers, snooker players, and golfers, to name just a few practitioners, all wield sticks-of-sorts in a skillful way. And so we arrive back at Ronnie O'Sullivan and a trajectory of hominid stick usage that takes us from its perceived beginnings, as imagined through Kubrick's ape, to its zenith, the Crucible Theatre, Sheffield, April 1997, and the fastest maximum break in history.

Yet Kubrick could just as well have substituted the bone with a stone, and in doing so may well have been more accurate in his portrayal of seminal tool adoption. While stones and bones survive in the archaeological record of early prehistory, it's hard to know, unless there are obvious



diagnostic signs of wear or modification, if a bone has been used for adapted purposes. Wooden sticks present an even more challenging situation by virtue of the fact that, unless suspended in the extreme environmental conditions of desiccation or saturation, they decompose and turn to dust. Stones, on the other hand, survive the ravages of time and make it abundantly clear to us when they have been refashioned or altered by the human hand. Thus they provide the earliest evidence for the human use of tools and have come to define the way we understand the development of human societies from around 3 to 4 million years ago until at least the Bronze Age (circa 2500–800 B.C.).

The byword in archaeology for stones is "-lith," ultimately deriving from the Greek *λίθος*, meaning "stone." It is on the basis of a stone-tool typology that we have been able to establish a chronology for the Stone Age. From the Palaeolithic (the "old" Stone Age) through the Mesolithic ("middle") to the Neolithic ("new"), stone tools become progressively more complex. It's a story that begins around 3 million years ago at a place called Olduvai Gorge on the Serengeti Plains of Tanzania, and includes the work of the British-Kenyan palaeoanthropologists and archaeologists Mary and Louis Leakey and their excavations in the 1950s. Here skeletal remains of *Australopithecus*, an early apelike hominid, were recovered, alongside associated assemblages of worked stone. These early tools are usually labeled pebble or cobble tools because they appear to have been

That seminal moment of creating a weapon or tool signals a new dawn in human technical advancement.

struck only enough times to create a single sharp edge. So these early tools were really very basic. Yet for *Australopithecus*, whose diet comprised scavenged meat, they were undoubtedly a step up from pulling apart a carcass with their bare hands, and allowed for the scoring of the hide, severing flesh, and the breaking and crushing of bones to release marrow. This small but significant step would lead to increased protein consumption and thus had a long-term evolutionary impact.

Then, around 1.9 million years ago, *Homo habilis* arrives on the archaeological scene, shortly followed, at around 1.2 million years ago, by Homo erectus. We now start to talk of hominins—members of the human clade—defined against the wider classification of hominid, which contained more apelike members of the genus, such as *Australopithecus africanus*. We tend to call the worked flints from this period Acheulean, after an archaeological site located at St. Acheul on the outskirts of Amiens, northern France. Here, in the 19th century, a number of what were termed hand axes were recovered from the gravel river terraces of the Somme region. In some ways, it was at this point that the Stone Age was born, as the incontrovertible evidence of stones that had been altered by human endeavor, associated with geological deposits of known age, forced a reconsideration of the traditional biblical narrative of how we were created.

Acheulean hand axes are beautiful artifacts to behold. For my first ever lecture on archaeological illustration at the Institute of Archaeology in London I had to make a technical drawing of one of these axes. As I turned it over in my hands I marveled at its epic journey through time. These beautifully worked flints show obvious signs of repeated striking to work a core down to a finished axe that has sharp edges on two sides converging on a tip, but with a "hold" at its base or distal end. What is so mesmerizing about them is that, written into their fracture lines, one can see the consciously made decisions and the cognitive processes of design as the lower Palaeolithic knapper conceived the desired shape and form. Here was something truly "human." The term hand axe is, however, probably a bit of a misnomer.

On an experimental trip to the dense woodlands of the Sussex Weald in the late 1990s, a few friends and I decided to see if we could fell a tree with crudely made versions of our own. Proponents of the original Palaeolithic Acheulean school would have undoubtedly winced at the standard of our replications, hurriedly knocked out in the back garden of a terraced house in Haringey one hot summer day, before catching the train down to Sussex. But ours certainly had sharp edges, and some very willing experimental archaeologists happy to spend a weekend hacking the trunk of a tree with them. In truth, the endeavor lasted little more than a few hours. Our arms and wrists quickly tired, joints started to seize and swell, and regularly swapping hands only served to spread the agony. So traumatized were the bones and muscles in our wrists that we could barely lift the consolatory pints to our lips at the local country pub that evening. Sucking ale through brightly colored straws, we all concluded that we should probably view

SUPER STICK
Ronnie O'Sullivan earned £515.63 per second at the 1997 snooker world championship.

the hand axe as an Acheulean Swiss Army Knife or Leatherman, a kind of multi-purpose tool. We are now encouraged by the experts to envisage hand axes as having a range of functions, including basic butchery, breaking, chopping, scraping, crushing, and digging, as well as being a form of currency.

The end of the Acheulean industry broadly overlaps with the emergence of *Homo neanderthalensis* and *Homo sapiens* between 100,000 and 125,000 years ago. With this ushering in of the middle Palaeolithic comes a much more developed attitude toward tool production and an increased sophistication in terms of social order. While artistic and symbolic representations were perhaps beyond their consciousness, their burial practices and other rituals are evidence of a capacity for abstract thought and a degree of self-awareness. Stone tools of this period are often referred to

as Mousterian, after the type site of Le Moustier in the Dordogne where some of the earliest most complete assemblages were found. Hand axes continued to be standard fare, but the period is also characterized by what we call "scrapers"—small hand-held flints around the blunt side of which the index finger is wrapped to create an effective cutting tool. These scrapers were almost certainly used in the preparation of hides, and the remarkable resilience of both *neanderthalensis* and *sapiens* in the face of climatic variation suggests that more sophisticated protective clothing was being produced.

Despite this, *Homo neanderthalensis* is thought to have died out at around 40,000 B.C., at the beginning of what was an extremely cold period for Europe. From here on, from the upper Palaeolithic into the Mesolithic, stone tool manufacture is characterized by much variation, innovation, and rapid development. Not only were the stone tools more sophisticated but they were also used to create bone tools such as awls and needles. Both suggest further developments in clothing and the likelihood that composite garments were stitched together for a tighter and more ergonomic fit. I often say to friends in the bespoke tailoring trade that it is to *Homo sapiens* of the upper Palaeolithic that their craft owes its greatest debt. Without those needles and custom-fit lines we might never as a species have survived that cold snap.

In the stone tool record local traditions are also evident, a sure sign that *Homo sapiens* had the capacity to adapt production to local environmental conditions. We can almost start to talk of "cultures" because of the variation in what are termed blade flakes—tools made from the flakes knocked from the core. It seems surprising that it took so long to work out that the bits flying off the core were as sharp as the core itself. Back in our garden

Over the last couple of years I've given in to an urge; I have started making sticks.

in Haringey it took a matter of minutes before barefoot flatmates found just how sharp a casual scattering of waste flints—or "debitage" as it's technically known—could be. But the innovation wasn't that tools were being made from off-cast flint but rather that the core was prepared in this way in order to purposely produce blade flakes from it. It's also obvious from analysis of the flakes, cores, platforms, and what we call the "bulb of percussion" that a whole range of fabrication techniques was being used. Indirect percussion (rather like the method of hammer and chisel), pressure flaking, and soft-hammer percussion (with an antler, for example) all allowed the upper Palaeolithic knapper to create a vast variety of stone tools that supported a very sophisticated relationship with the natural world. If this short history has captured your imagination then I advise booking yourself onto an introductory flint-knapping course. It's easy to become lost in the immersive world of smacking stone on stone; it's an enormously therapeutic pastime, and one that allows you to connect with the innate *Homo sapiens* in yourself. There truly is no more authentic way of getting back to basics.

The key technological development in this period is the evidence for hafting—the fixing of a spearhead or arrowhead onto the end of a stick. The evidence comes not from the excavation of complete weapons—wooden shafts with blades attached—but from the shape of the worked flints and the presence of side and corner notches at their base. These indentations cut into the flints would provide purchase for a length of cord used to bind the blade to the stick. There has been a long-standing debate as to whether, as early as the Mousterian industry, projectile points were hafted, but recently excavations at Kathu Pan in South Africa have recovered a number of stone points whose tips exhibit fracture types that indicate impact rather than scraping and sawing. Furthermore, modifications near the base of these points were consistent with hafting. The scientific dating from the site proposes a date range centering around 500,000 years ago. This is an incredible 200,000 years earlier than conventionally thought and forces us to rethink man as hunter rather than hunted at a much earlier period in our evolutionary models. What is certain is that these crude attempts were nowhere near as sophisticated as the projectile points hafted in the Mesolithic, nor those still produced today by cultures in the Amazon rainforests of South America.

Hafting—the technological capacity to attach a stick to a stone—really is the point at which craft becomes cemented as an evolutionary option for the human species. The composite tool or utensil was born, and with it the capacity to make at a much more advanced level than before. That seminal moment of creating a weapon or tool is, in my opinion, a crucial coming together. It is an event that signals a new dawn in human technical advancement—effectively the creation of an extended limb—and one that is certainly well developed by the Mesolithic. Whether it began 500,000 or 300,000 years ago, I'd like to pick up the hafting story in its final days, somewhere in the 1950s, with my grandfather, the former golf-club maker.

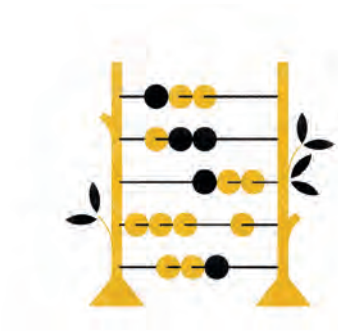
OVER THE LAST COUPLE OF YEARS I've given in to an urge; it's a subliminal longing and a deep genetic inheritance. I have started making sticks.

It's addictive—and evidently in my blood. I blame my grandfather on my father's side. He passed away when I was only 2, so I never really knew him. He was born, lived, and died in St. Andrews—the home of golf—and he plied his trade in the golf-club-making industry. He was, therefore, a stick maker par excellence and a man of considerable skill. My father recalls how, as a boy, he would watch in awe as his father sat outside at the back of the house turning lengths of hazel, ash, or willow into walking sticks. The scene was to repeat itself a generation later as I watched my own father sitting on the back step, whittling away in the evening sunlight. I can't remember a time when my dad didn't have a stick or two on the go, carving intricate figures into the handles and decorative patterns into the shafts. But I never once thought I would find myself in his place, daydreaming while my hands took over the work.

Among the many manual skills required to make a golf club, one of my grandfather's specialisms was the whipping of the club head and handle to the shaft. It was a relatively simple process but one that was absolutely necessary to get right if the joint between the head and the shaft was not to fracture, open up under duress, and eventually split apart. It involved taking a piece of cord and binding it around the joint as a means of reinforcing it. With one hand, pressure had to be kept on the cord at all times to keep maximum tension while the other hand slowly turned the head of the club to wind the cord on. The job was completed in such a way as to conceal the knot and give it a smooth finish, for appearance's sake but also so that no trailing cord was left to snag and weaken the bind. Although robbed of an arena within which to use his craft, Grandad passed down to his son the skill of whipping and, in turn, my father has passed it down to me.

I've had cause to use this inherited and versatile skill on a number of occasions, most recently in attempting to make a late medieval/early

When the machines took over this process we lost a direct and tangible link with our ancient ancestry.



modern fishing rod. In a text called *The Treatyse of Fishing with an Angle*, dated to the late 15th century, a type of fishing rod made from hazel and a length of horsehair line is described in some detail. Hazel is a wonderful wood for creating fishing rods. Grown in the shade and in wet, humus-rich soil, it can attain dead-straight lengths of 10 to 12 feet while remaining remarkably thin. It's flexible too, so it can take the strain of the fish as it tries to wriggle free of the hook. Where it falls short is in the weakness of the soft wood at its thinner end. This is prone to snapping under the slightest pressure. Therefore, a small wand of harder wood—such as blackthorn or applewood—needs splicing onto the hazel at a thickness where it's strong enough to take the joint. The two woods are bound together using the technique of whipping, which can also be used to create a grip on the butt end of the rod. By the time I'd finished, my fishing rod certainly looked the part. Pity then that I had neither the patience nor the skill to fish.

It was on the first occasion I had to use whipping that I realized just how ancient the technique was. I was trying to fasten a flint spearhead, which I'd spent a good two days producing from scratch, onto a shaft of ash that I'd bark-stripped with a flint scraper. I was feeling rather smug, for this was the kind of thing I used to do as a kid with schoolfriends during long hot summers spent in the spinneys, holts, and coppices that border Pevensey Marsh in Sussex. Now, as a student in higher education, with an interest in experimental archaeology, I could dress it up as "research" to justify the hours spent returning to the halcyon days of my youth. I was going for something with an upper Palaeolithic feel; something with which I could burst out from behind a hedge and take down a young caribou—or at least that's what I imagined.

I experimented with indirect percussion and pressure flaking in the process of making my arrowhead, and used commercial cordage for the whipping. I'd hoped to make my own string from the stems of nettle plants, but was rapidly running out of time—a common problem when trying to cram the Palaeolithic into a three-day weekend. As I sat in the dappled light of the woodland floor, intently concentrating on the binding process, it dawned on me just how far this skill, or technique, had traveled. It had passed through hundreds of thousands of generations, crossed

continents, spanned epochs, and fulfilled a multiplicity of functions on its way. And here I was, using it by virtue of the time taken by my father and by his father before him to pass it on. It told a story that was as important to our understanding of humanity as any written history, a tale of ordinary people who relied on such skills for their sustenance. When the machines took over this process in the golf-club-making industry of St Andrews, my grandad lost his livelihood and his source of pride, but we, the wider society, lost a direct and tangible link with our ancient ancestry.

I would love to be able to tell the parallel evolutionary story of stick development since the lower Palaeolithic, for it's almost inconceivable that *Australopithecus, Homo habilis, erectus, neanderthalensis* and *sapiens* did not develop this technology to the same degree of sophistication as they had stone-tool technology. But because of wood's inability to survive in the archaeological record, it will forever be a story that remains untold and one merely hypothesized by the daydreaming of experimental archaeologists such as myself. Even if we can't chart the development and diversity of its usage in primitive society, we should at least thank the stick, the stone's silent sister in the archaeological record, for the part it played in developing the cognitive processes of the human species.

ALEXANDER LANGLANDS is an archaeologist and medieval historian. He is a regular presenter for the BBC and a professor of medieval history at Swansea University.

56

THE IMPORTANCE OF PERSPECTIVE IN SCIENCE cannot be understated and yet often is. From the outside, science can seem like a common noun, a smooth and untextured monolith containing the Truth.

But science is a method and not a body of knowledge, and it is practiced by fallible humans. They bring their individual upbringings and passions to their work, with each perspective expanding on the next. In that sense, science and scientists can be as complex as their subject. It lifts us out of ignorance and gains a unique power against bias precisely because of its effort to shed light on the biases of its practitioners.

This issue ends with a story titled "Autistic Prodigies Since Rain Man," in which science writer Ann Hulbert introduces us to Darold A. Treffert, a soft-spoken Wisconsin psychiatrist in his 80s called the "godfather of savant research." He banished the idiot prefix and challenged us to wrestle with what those different from ourselves teach us about the nature of intelligence itself.

Welcome to "Perspective."

—MS

"You are of royal descent, because everyone is. You are of Viking descent, because everyone is. You are of Saracen, Roman, Goth, Hun, Jewish descent, because, well, you get the idea."

ADAM RUTHERFORD
"You're Descended from Royalty and So Is Everybody Else" p.36

Perspective

THE OTHER WAY AROUND

You're Descended from Royalty and So Is Everybody Else

Anybody you can name from ancient history is in your family tree

BY ADAM RUTHERFORD

CHARLEMAGNE, CAROLINGIAN KING OF THE FRANKS, Holy Roman Emperor, the great European conciliator; your ancestor. I am making an assumption that you are broadly of European descent, which is not statistically unreasonable but certainly not definitive. If you're not, be patient, and we'll come to your own very regal ancestry soon enough.

Along with Alexander and Alfred, Charlemagne is one of a handful of kings who gets awarded the postnominal accolade "the Great." His early life remains mysterious and the stories are assembled from various sources, but it seems he was born around 742 A.D., just at the time when the Plague of Justinian was dispatching millions at the eastern edge of the moribund Roman Empire. The precise place of his birth is also unknown, but it's likely to be in a town such as Aachen, now in contemporary Germany, or Liège in Belgium. Even Einhard, his dedicated servant and biographer, wouldn't get drawn into the specifics of Charlemagne's early life in his fawning magnum opus, *The Life of Charles the Great*. The very fact that this account exists—probably the first biography of a European ruler—is testament to how important he was (or at least was seen to be). In many European languages, the word "king" is itself derived from Charlemagne's name.

He was the son of Pippin the Short, an aggressive ruler of France who expanded the Frankish kingdom until his death during the return journey from a campaign against the persistently rebellious realm of Aquitaine in 768. Charlemagne stepped up as his successor, and continued the expansion with aplomb. He battled the Saxons to the northeast, the Lombards in Italy, and Muslims in Spain. He capitalized on his father's good political relations with the Vatican, and in 800 was crowned the first Holy Roman Emperor by Pope Leo III in St Peter's Basilica, an event so momentous that Charlemagne marked it by giving Leo one of the great medieval relics as a thank you—the Holy Prepuce, better known as Jesus' foreskin.

A fecund ruler, Charlemagne sired at least 18 children by motley wives and concubines, including nine by his second wife, Hildegard of Vinzgau. These kin included Charles the Younger, Pippin the Hunchback, Drogo of Metz, Hruodrud, Ruodhaid, Adalheid, Hludowic, and not forgetting Hugh, and he consolidated his reign by installing many of his sons in positions of power across the expanding empire. Royal lineages are historically the only ones to get documented well until the modern era, and Charlemagne's lineage is bountiful. We can trace a path directly from his fruitful loin: It begins with his son Louis the Pious, via Lothar, Bertha, Willa, Rosele, eight men called Baldwin, and so on through the ages until it reaches the 21st century in a Dutch family called the Backer-Dirks, whose family tree all the way back to the king is publicly available online.

This pedigree, by gorgeous chance, also contains Joachim Neumann, a 17th-century German Protestant preacher, who sought peace and meditation away from the political machinations and church hullabaloo of Dusseldorf in a small cave near the river Dussel. He had changed his name from Neumann to a Greek version with the same meaning: new man. He wasn't the only new man in that cave. This was the location of the very first new human to be identified, a century later, in the valley of Joachim Neander—Neanderthal man.

What a lineage to behold! It comes as no great surprise that in the world of amateur genealogy, being descended from imperial royalty is considered of high cachet. In fact, descent from anyone actually named from history brings prestige, as the vast majority of humans have drifted into and out of existence leaving little or no historical footprint that shows they ever drew breath. To be drawn from the bloodline of a king, and not just any old Holy Roman Emperor, but the very first, must be momentous.

Christopher Lee—the great actor who among his roles counts Dracula; Tolkien's Saruman the White; the Man with the Golden Gun himself, Scaramanga; the fallen Jedi Count Dooku; and *The Wicker Man*'s Lord Summerisle—claimed direct ancestry to King Charlemagne via the ancient house of his mother, Countess Estelle Marie (née Carandini di Sarzano):

> The Carandini family is one of the oldest in Europe and traces itself back to the first century A.D. It is believed to have been connected with the Emperor

PHOTO COLLAGE CREDITS: PIXABAY; WIKIPEDIA

Charlemagne, and as such was granted the right to bear the coat of arms of the Holy Roman Empire by Emperor Frederick Barbarossa.*

MAYBE IT WAS TO ENHANCE his august yet sinister screen image as having played some of the wickedest characters in film history. Most people don't have a coat of arms, but I can say with absolute confidence that if you're vaguely of European extraction, just like cinema's greatest Prince of Darkness, you are descended from Charlemagne too. Hail to the king!

We are all special, which also means that none of us is. This is merely a numbers game. You have two parents, four grandparents, eight great-grandparents, and so on. Each generation back the number of ancestors you have doubles. But this ancestral expansion is not borne back ceaselessly into the past. If it were, your family tree when Charlemagne was Le Grand Fromage would harbor around 137,438,953,472 individuals on it—more people than were alive then, now, or in total. What this means is that pedigrees begin to fold in on themselves a few generations back, and become less arboreal, and more a mesh or weblike. You can be, and in fact are, descended from the same individual many times over. Your great-great-great-great-great-grandmother might hold that position in your family tree twice, or many times, as her lines of descent branch out from her, but collapse onto you. The further back through time we go, the more these lines will coalesce on fewer individuals. "Pedigree" is a word derived from the middle French phrase "*pied de grue*"—the crane's foot—as the digits and hallux spread from a single joint at the bottom of the tibia, roughly equivalent to our ankle. This branching describes one or a few generations of a family tree, but it's wholly inaccurate as we climb upward into the past. Rather, each person can act as a node into whom the genetic past flows, and from whom the future spills out, if indeed they left descendants at all.

This I find relatively easy to digest. The simple logic is that there are more living people on Earth now than at any single moment in the past, which means that many fewer people act as multiple ancestors of people alive today. But how can we say with utter confidence that any individual European is, like Christopher Lee, directly descended from the great European conciliator?

The answer came before high-powered DNA sequencing and ancient genetic analysis. Instead it comes from mathematics. Joseph Chang is a statistician from Yale University and wished to analyze our ancestry not with genetics or family trees, but just with numbers. By asking how recently the people of Europe would have a common ancestor, he constructed a mathematical model that incorporated the number of ancestors an individual is presumed to have had (each with two parents), and given the current population size, the point at which all those possible lines of ascent up the family trees would cross. The answer was merely 600 years ago. Sometime at the end of the 13th century lived a man or woman from whom all Europeans could trace ancestry, if records permitted (which they don't). If this sounds unlikely or weird, remember that this individual is one of thousands of lines of descent that you and everyone else has at this moment in time, and whoever this unknown individual was, they represent a tiny proportion of your total familial webbed pedigree. But if we could document the total family tree of everyone alive back through 600 years, among the impenetrable mess, everyone European alive would be able to select a line that would cross everyone else's around the time of Richard II.

Chang's calculations get even weirder if you go back a few more centuries. A thousand years in the past, the numbers say something very clear, and a bit disorienting. One-fifth of people alive a millennium ago in Europe are the ancestors of no one alive today. Their lines of descent petered out at some point, when they

Sometime at the end of the 13th century lived a man or woman from whom all Europeans could trace ancestry.

*As reported by University College Dublin on awarding Christopher Lee Honorary Life Membership of their Law Society in 2011.

WIKIPEDIA

or one of their progeny did not leave any of their own. Conversely, the remaining 80 percent are the ancestor of everyone living today. All lines of ancestry coalesce on every individual in the 10th century.

One way to think of it is to accept that everyone of European descent should have billions of ancestors at a time in the 10th century, but there weren't billions of people around then, so try to cram them into the number of people that actually were. The math that falls out of that apparent impasse is that all of the billions of lines of ancestry have coalesced into not just a small number of people, but effectively literally everyone who was alive at that time. So, by inference, if Charlemagne was alive in the ninth century, which we know he was, and he left descendants who are alive today, which we also know is true, then he is the ancestor of everyone of European descent alive in Europe today.

It's not even relevant that he had 18 children, a decent brood for any era. If he'd had one child who lived and whose family propagated through the ages until now, the story would be the same. The fact that he had 18 increases the chances of his being in the 80 percent rather than the 20 percent who left no 21st-century descendants, but most of his contemporaries, to whom you are all also directly related, will have had fewer than 18 kids, and some only one, and yet they are all also in your family tree, unequivocally, definitely, and assuredly.

At least that's the theory. With the advent of easy and cheap DNA sequencing came the possibility of testing this math. DNA is the bearer of biological ancestry, and you get all of your DNA from your two parents, pretty much a 50:50 split. They in turn got all of their DNA from their parents, so one quarter of your DNA is the same as a quarter of each of your grandparents. If you have a cousin, then you share around an eighth of your DNA, as you have a pair of grandparents in common. These shared bits of DNA are not the same sections though. And it doesn't keep halving perfectly as you meander up through your family tree. Remember that DNA gets shuffled when a sperm or egg is made, and every single shuffle is different, but it's quite clumsy shuffling. In the newly shuffled deck, that is, your own personal genome, big chunks of it are the same as your father or mother. The more closely related two people are, the more DNA they will share in big chunks. This is why identical twins are identical (all the chunks are the same), and why siblings and parents look similar (half of their DNA is the same as each other). In genetics, we call these sections of DNA identical by descent, and they are very useful for measuring the relatedness of two individuals.

In 2013, geneticists Peter Ralph and Graham Coop showed that DNA says exactly the same thing as Chang's mathematical ancestry: Our family trees are not trees at all, but entangled meshes. They looked

for lengths of identical by descent DNA in 2,257 people from around Europe (to mitigate the influence of recent migration, all the subjects selected had four grandparents from the same region or country). By measuring the lengths of the shared DNA, they could estimate how long ago that deck got shuffled, and therefore how related any two people are. Computing and DNA have empowered this field, and this is shown in their dataset and the number crunching that follows.

Joseph Chang's mathematical calculation didn't account for something very obvious, which is that we don't mate randomly. We typically marry within socioeconomic groups, within small geographical areas, within shared languages. But with Coop and Ralph's genetic analysis, it didn't seem to matter that much. Ancestry is such that genes can spread very quickly over generations. It might seem that a remote tribe would have been isolated from others for centuries in, for example, the Amazon. But no one is isolated indefinitely, and it only takes a very small number of people to breed out with people from beyond their direct gene pool for that DNA to rapidly descend through the generations.

> DNA says exactly the same thing as mathematical ancestry: Our family trees are not trees at all, but entangled meshes.

Chang factored that into a further study of common ancestry beyond Europe, and concluded in 2003 that the most recent common ancestor of everyone alive today on Earth lived only around 3,400 years ago.

He used two calculations, one that simply crunched the math of ancestry, and another that incorporated a simplified model of towns and migration and ports and people. In the computer model, a port has a higher rate of immigration, and growth rates are higher. With all these and other factors input, the computer calculates when lines of ancestry cross, and the number comes out at around 1400 B.C. It places that person somewhere in Asia, too, but that is more likely to do with the geographical center point from which the migrations are calculated. If this sounds too recent, or baffling because of remote populations in South America or the islands of the South Pacific, remember that no population is known to have remained isolated over a sustained period of time, even in those remote locations. The influx of the Spanish into South America meant their genes spread rapidly into decimated indigenous tribes, and eventually to the most remote peoples. The inhabitants of the minuscule Pingelap and Mokil atolls in the mid-Pacific have incorporated Europeans into their gene pools after they were discovered in the years of the 19th century. Even religiously isolated groups such as the Samaritans, who number fewer than 800 and are sequestered within Israel, have elected to outbreed in order to expand their limited gene pool.

When Chang factored in new, highly conservative variables, such as reducing the number of migrants

PIXABAY

across the Bering Straits to one person every 10 generations, the age of the most recent common ancestor of everyone alive went up to 3,600 years ago.

This number may not feel right, and when I talk about it in lectures, it often results in a frown of disbelief. We're not very good at imagining generational time. We see families as discrete units in our lifetimes, which they are. But they're fluid and continuous over longer periods beyond our view, and our family trees sprawl in all directions. The concluding paragraph of Chang's otherwise tricky mathematical and highly technical study is neither of those things. It's beautiful writing, extremely unusual in an academic paper, and it deserves to be shared in full:

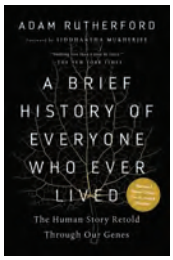
> Our findings suggest a remarkable proposition: No matter the languages we speak or the color of our skin, we share ancestors who planted rice on the banks of the Yangtze, who first domesticated horses on the steppes of the Ukraine, who hunted giant sloths in the forests of North and South America, and who laboured to build the Great Pyramid of Khufu.

You are of royal descent, because everyone is. You are of Viking descent, because everyone is. You are of Saracen, Roman, Goth, Hun, Jewish descent, because, well, you get the idea. All Europeans are descended from exactly the same people, and not that long ago. Everyone alive in the 10th century who left descendants is the ancestor of every living European today, including Charlemagne, and his children Drogo, Pippin, and, of course, not forgetting Hugh. If you're broadly eastern Asian, you're almost certain to have Genghis Kahn sitting atop your tree somewhere in the same manner, as is often claimed. If you're a human being on Earth, you almost certainly have Nefertiti, Confucius, or anyone we can actually name from ancient history in your tree, if they left children. The further back we go, the more the certainty of ancestry increases, though the knowledge of our ancestors decreases. It is simultaneously wonderful, trivial, meaningless, and fun.

The truth is that we all are a bit of everything, and we come from all over. Even if you live in the most remote parts of the Hebrides, or the edge of the Greek Aegean, we share an ancestor only a few hundred years ago. A thousand years ago, we Europeans share all of our ancestry. Triple that time and we share all our ancestry with everyone on Earth. We are all cousins, of some degree. I find this pleasing, a warm light for all mankind to share. Our DNA threads through all of us.

Ancestry is messy and difficult. Genetics is messy and mathematical, but powerful if deployed in the right way. People are horny. Lives are complex. A secret history is truly hidden in the mosaics of our genomes, but *caveat emptor*. No scientific test exists that will tell you where the DNA that you would come to inherit was precisely located in the past. Human history is replete with the fluid movement of people, and tribes and countries and cultures and empires are never, ever permanent. Over a long enough timescale, not one of these descriptions of historical people holds steadfast, and only 1,000 years ago your DNA began being threaded from millions from every culture, tribe, and country. If you want to spend your cash on someone in a white coat telling you that you're from a tribe of wandering Germanic topless warriors, or descended from Vikings, Saracens, Saxons, or Drogo of Metz, or even the Great Emperor Charlemagne, help yourself. I, or hundreds of geneticists around the world, will shrug and do it for free: You are. And you don't even need to spit in a tube—your majesty.

ADAM RUTHERFORD is a geneticist, author, and broadcaster. He was an editor at *Nature*, and is a frequent contributor to *The Guardian*.



An excerpt from *A Brief History of Everyone Who Ever Lived* by Adam Rutherford. Reprinted by permission of the publisher, The Experiment. Available wherever books are sold.

Antonio Damasio Tells Us Why Pain Is Necessary

The neuroscientist explains why feelings evolved

BY KEVIN BERGER

PHOTO BY LUIZ CARVALHO

FOLLOWING OLIVER SACKS, ANTONIO DAMASIO may be the neuroscientist whose popular books have done the most to inform readers about the biological machinery in our heads, how it generates thoughts and emotions, creates a self to cling to, and a sense of transcendence to escape by. But since he published *Descartes' Error* in 1994, Damasio has been concerned that a central thesis in his books, that brains don't define us, has been muted by research that states how much they do. To Damasio's dismay, the view of the human brain as a computer, the command center of the body, has become lodged in popular culture.

In his new book, *The Strange Order of Things*, Damasio, a professor of neuroscience and the director of the Brain and Creativity Institute at the University of Southern California, mounts his boldest argument yet for the egalitarian role of the brain. In "Why Your Biology Runs on Feelings," an online article on *Nautilus*, drawn from his new book, Damasio tells us "mind and brain influence the body proper just as much as the body proper can influence the brain and the mind. They are merely two aspects of the very same being."

The Strange Order of Things offers a sharp and uncommon focus on feelings, on how their biological evolution fueled our prosperity as a species, spurred science and medicine, religion and art. "When I look back on *Descartes' Error*, it was completely timid compared to what I'm saying now," Damasio says. He knows his new book may rile believers in the brain as emperor of all. "I was entirely open with my ideas," he says. "If people don't like it, they don't like it. They can criticize it, of course, which is fair, but I want to tell them, because it's so interesting, this is why you have feelings."

In this interview with *Nautilus*, Damasio, in high spirits, explains why feelings deserve a starring role in human culture, what the real problem with consciousness studies are, and why Shakespeare is the finest cognitive scientist of them all.

One thing I like about *The Strange Order of Things* is it counters the idea that we are just our brains.
Oh, that idea is absolutely wrong.

Not long ago I was watching a PBS series on the brain, in which host and neurologist David Eagleman, referring to our brain, declares, "What we feel, what matters to us, our beliefs and our hopes, everything we are happens in here."
That's not the whole story. Of course, we couldn't have minds with all of their enormous complexity without nervous systems. That goes without saying. But minds are not the result of nervous systems alone. The statement you quote reminds me of Francis Crick, someone whom I admired immensely and was a great friend. Francis was quite opposed to my views on this issue. We would have huge discussions because he was the one who said that everything you are, your thoughts, your feelings, your mental this and that, are nothing but your neurons. This is a big mistake, in my view, because we are mentally and behaviorally far more than our neurons. We cannot have feelings arising from neurons alone. The nervous systems are in constant interaction and cooperation with the rest of the organism. The reason why nervous systems exist in the first place is to assist the rest of the organism. That fact is constantly missed.

The concept of "homeostasis" is critical in your new book. What is homeostasis?
It's the fundamental property of life that governs everything that living cells do, whether they're living cells alone, or living cells as part of a tissue or an organ, or a complex system such as ourselves. Most of the time, when people hear the word homeostasis, they think of balance, they think of equilibrium. That is incorrect because if we ever were in "equilibrium," we would be dead. Thermodynamically, equilibrium means zero thermal differences and death. Equilibrium is the last thing that nature aims for.

What we must have is efficient functioning of a variety of components of an organism. We procure energy so that the organism can be perpetuated, but then we do something very important and almost always missed, which is hoard energy. We need to maintain positive energy balances, something that goes beyond what we need right now because that's what ensures the future. What's so beautiful about

homeostasis is that it's not just about sustaining life at the moment, but about having a sort of guarantee that it will continue into the future. Without those positive energy balances, we court death.

What's a good example of homeostasis?

If you are at the edge of your energy reserves and you're sick with the flu, you can easily tip over and die. That's one of the reasons why there's fat accumulation in our bodies. We need to maintain the possibility of meeting the extra needs that come from stress, in the broad sense of the term. I poetically describe this as a desire for permanence, but it's not just poetic. I believe it's reality.

You write homeostasis is maintained in complex creatures like us through a constant interplay of pleasure and pain. Are you giving a biological basis to Freud's pleasure principle—life is governed by a drive for pleasure and avoidance of pain?

Yes, to a great extent. What's so interesting is that for most of the existence of life on earth, all organisms have had this effective, automated machinery that operates for the purpose of maintenance and continuation of life. I like to call the organisms that only have that form of regulation, "living automata." They can fight. They can cooperate. They can segregate. But there's no evidence that they know that they're doing so. There's no evidence of anything we might call a mind. Obviously we have more than automatic regulation. We can control regulation in part, if we wish to. How did that come about?

Very late in the game of life there's the appearance of nervous systems. Now you have the possibility of mapping the inside and outside world. When you map the inside world, guess what you get? You get feelings. Of necessity, the machinery of life is either in a state of reasonable efficiency or in a state of inefficiency, which is most often the case. Organisms with nervous systems can image these states. And when you start having imagery, you start having minds. Now you begin to have the possibility of responding in a way that you could call "knowledgeable." That happens when organisms make images. A bad internal state would have been imaged as the first pains, the first malaises, the first sufferings. Now the organism has the possibility of knowingly avoiding whatever caused the pain or prefer a place or a thing or another animal that causes the opposite of that, which is well-being and pleasure.

Why would feelings have evolved?

Feelings triumphed in evolution because they were so helpful to the organisms that first had them. It's important to understand that nervous systems serve the organism and not the other way around. We do not have brains controlling the entire operation. Brains adjust controls. They are the servants of a living organism. Brains triumphed because they provided something useful: coordination. Once organisms got to the point of being so complex that they had an endocrine system, immune system, circulation, and central metabolism, they needed a device to coordinate all that activity. They needed to have something that would simultaneously act on point A and point Z, across the entire organism, so that the parts would not be working at cross purposes. That's what nervous systems first achieve: making things run smoothly.

Now, in the process of doing that, over millions of years, we have developed nervous systems that do plenty of other things that do not necessarily result in coordination of the organism's interior, but happen to be very good at coordinating the internal world in relation to the outside world. This is what the higher reaches of our nervous system, namely the cerebral cortex, does. It gives us the possibilities of perceiving, of memorizing, of reasoning over the knowledge that we memorize, of manipulating all of that and even translating it into language. That is all very beautiful, and it is also homeostatic, in the sense that all of it is convenient to maintain life. It if were not, it would just have been discarded by evolution.

How does your thesis square with the hard problem of consciousness, how the physical tissue in our heads produces immaterial sensations?

Some philosophers of mind will say, "Well, we face this gigantic problem. How does consciousness emerge out of these nerve cells?" Well, it doesn't. You're not dealing with the brain alone. You have to think in terms of the whole organism. And you have to think in evolutionary terms.

The critical problem of consciousness is subjectivity.

The importance of feeling is that it makes you critically aware of what you are doing in moral terms.

You need to have a "subject." You can call it an *I* or a *self*. Not only are you aware right now that you are listening to my words, which are in the panorama of your consciousness, but you are aware of being alive, you realize that you're there, you're ticking. We are so distracted by what is going on around us that we forget sometimes that we *are*, A-R-E in capitals. But actually you are watching what you are, and so you need to have a mechanism in the brain that allows you to fabricate that part of the mind that is the watcher.

You do that with a number of devices that have to do, for example, with mapping the movements of your eyes, the position of your head, and the musculature of your body. This allows you to literally construct images of yourself making images. And you also have a layer of consciousness that is made by your perception of the outside world; and another layer that is made of appreciating the feelings that are being generated inside of you. Once you have this stack of processes, you have a fighting chance of creating consciousness.

Why do you object to comparing the brain to a computer?

In the early days of neuroscience, one of our mentors was Warren McCulloch. He was a gigantic figure of neuroscience, one of the originators of what is today computational neuroscience. When you go back to the '40s and '50s, you find this amazing discovery that neurons can be either active or inactive, in a way that can be described mathematically as zeroes and ones. Combine that with Alan Turing and you get this idea that the brain is like a computer and that it produces minds using that same simple method.

That has been a very useful idea. And true enough, it explains a good part of the complex operations, that our brains produce such as language. Those operations require a lot of precision and are being carried out by the cerebral cortex, with enormous detail, and probably in a basic computational mode. All the great successes of artificial intelligence used this idea and have been concerned with high-level reasoning. That is why A.I. has been so successful with games such as chess or Go. They use large memories and powerful reasoning.

Are you saying neural codes or algorithms don't blend with living systems?

Well, they match very well with things that are high on the scale of the mental operations and behaviors, such as those we require for our conversation. But they don't match well with the basic systems that organize life, that regulate, for example, the degree of mental energy and excitation or with how you emote and feel. The reason is that the operations of the nervous system responsible for such regulation relies less on synaptic signaling, the one that can be described in terms of zeroes and ones, and far more on non-synaptic messaging, which lends itself less to a rigid all or none operation.

Perhaps more importantly, computers are machines invented by us, made of durable materials. None of those materials has the vulnerability of the cells in our body, all of which are at risk of defective homeostasis, disease, and death. In fact, computers lack most of the characteristics that are key to a living system. A living system is maintained in operation, against all odds, thanks to a complicated mechanism that can fall apart as a result of minimal amounts of malfunction. We are extremely vulnerable creatures. People often forget that. Which is one of the reasons why our culture, or Western cultures in general, are a bit too calm and complacent about the threats to our lives. I think we are becoming less sensitive to the idea that life is what dictates what we should do or not do with ourselves and with others.

What is love for?
To protect, to cause flourishing, to give and receive pleasure, to procreate, to soothe. Endless great uses, as you can see.

How do emotions such as anger or sadness serve homeostasis?
At individual levels, both anger and sadness are protective. Anger lets your adversary know that you mean business and that there may be costs to attacking you. These days anger is an expression of sociopolitical conflicts. It is overused and has largely become ineffectual. Sadness is a prelude to mental hibernation. It lets you retreat and lick your wounds. It lets you plan a strategy of response to the cause of the wounds.

You say feelings spurred the creation of cultures. How so?
Before I started *The Strange Order of Things*, I was asking friends and colleagues how they thought cultures had begun. Invariably what people said was, "Oh, we're so smart. We're so intellectually powerful. We have all this reasoning ability. On top of it all, we have language—and there you are." To which I say, "Fine, that's true. How would you invent anything if you were stupid?" You would not. But the issue is to recognize the motive behind what you do. Why is it that you did it in the first place? Why did Moses come down from the mountain with Ten Commandments? Well, the Ten Commandments are representative of homeostasis because they tell you not to kill, not to steal, not to lie, not to do a lot of bad things. It sounds trivial but it's not. We fail to think about motivation and so we do not factor it into the process of invention. We do not factor in the motives behind science or technology or governance or religion.

And there's one more thing: The importance of feeling is that it makes you critically aware of what you are doing in moral terms. It forces you to look back and realize that what people were doing historically, at the outset, at the moment of invention of a cultural instrument or a cultural practice, was an attempt to reduce the amount of suffering and to maximize the amount of well-being not only for the inventor, but for the community around them. One person alone can invent a painting or a musical composition, but it is not meant for that person alone. And you do not invent a moral system or a government system alone or for yourself alone. It requires a society, a community.

Religions have been one of the great causes of violence throughout history.

The assertion that intellect is governed by feelings can sound New Age-y. It seems to undermine the powers of reason. How should we understand reason if it's always motivated by subjective feelings?
Subjective simply means that it has a personal point of view, that it pertains to the self. It is compatible with "objective" facts and with truth. It is not about relativism. The fact that feelings motivate the use of knowledge and reason does not make the knowledge and the reason any less truthful or valid. Feelings are simply a call to action.

If humans formed societies and cultures to avoid suffering and pain, why do we have violence and wars?
Your question is very important. Take developments of political systems. On the face of it, when you look at Marxist ideas, you say, "This is obviously homeostatic." What Marx and others were trying to do in the 19th century is confront and modify a social arrangement that was not equitable, that had some people suffering too much and some profiting too much. So having a system that produced equality made a lot of sense. In a way that is something that biological systems have been trying to do, quite naturally, for a long time. And when the natural systems do not succeed at improved regulation, guess what? They are weeded out by evolution because they promote illness.

Biological evolution, through genetic selection, eliminates those mechanisms. At the cultural level something comparable occurs. Seen in retrospect, Marxism as applied in Russia resulted in one of the worst tragedies of humankind. But Russian communism was ultimately weeded out by cultural selection. It took around 70 years to do it, but cultural selection did operate in a homeostatic way. It led to the fall of the Berlin Wall and the Soviet empire. It was a homeostatic correction achieved by social means.

The same reasoning applies to religions. For example, we can claim that religions have been one of the great causes of violence throughout history. But you certainly can't blame Christ for that violence. He preached compassion, and the pardoning of enemies, and love. It does not follow that good recommendations can be implemented correctly and always produce good results. These facts in no way deny the homeostatic intent of religions.

You write, "The increasing knowledge of biology from molecules to systems reinforces the humanist project." How so?

This knowledge gives us a broader picture of who we are and where we are in the history of life on earth. We had modest beginnings, and we have incorporated an incredible amount of living wisdom that comes from as far down as bacteria. There are characteristics of our personal and cultural behavior that can be found in single-cell organisms or in social insects. They clearly do not have the kind of highly developed brains that we have. In some cases, they don't have any brain at all. But by analyzing this strange order of developments we are confronted with the spectacle of life processes that are complex and rich in spite of their apparent modesty, so complex and rich that they can deliver the high level of behaviors that we normally, quite pretentiously, attribute only to our great human smarts. We should be far more humble. That's one of my main messages. In general, connecting cultures to the life process makes apparent a link that we have ignored for far too long.

What would you be if you weren't a scientist?

When I was an adolescent, I often thought that I might become a philosopher or perhaps a playwright or filmmaker. That's because I so admired what philosophers and storytellers had found about the human mind. Today when people ask me, "Who's your most admired cognitive scientist?" I say Shakespeare. He knew it all and knew it with enormous precision. He didn't have the nice fMRI scanner and electrophysiology techniques we have in our Institute. But he *knew* human beings. Watch a good performance of *Hamlet*, *King Lear*, or *Othello*. All of our psychology is there, richly analyzed, ready for us to experience and appreciate.

KEVIN BERGER is *Nautilus*' features editor.

Autistic Prodigies Since *Rain Man*

Our evolving understanding of "the engineer's disease"

BY ANN HULBERT

THE LIST OF OFF-THE-CHARTS young achievers associated, in retrospect, with Asperger's syndrome extends a long way back. You may have heard that Bill Gates has been informally diagnosed with it. So, after the fact, has Bobby Fischer, obsessive and unable to look anybody in the eye. The label has been applied to Newton, Mozart, Yeats, and Wittgenstein, too. All of these recruits, of course, grew up well before the autism spectrum disorder—called by some "the engineers' disease"—claimed a place in the 1994 revision of the *Diagnostic and Statistical Manual of Mental Disorders*, psychiatry's authoritative guide. Nearly 20 years later, in 2013, the Asperger's label was officially dropped. But high-functioning autism had come trailing an aura of precocious genius, along with painful social cluelessness, and that aura was here to stay. The very bright yet remote "little professor" profile has become, as a journalist put it, "a signature disorder of the high-tech information age." Unofficially the diagnosis, rooted in descriptions published in 1944 by the Viennese pediatrician Hans Asperger, is still with us—a portent of struggle, surely, yet also perhaps of unusual potential. Hadn't Asperger said that "for success in science and art a dash of autism is essential"?

An unsettling experience, or some version of it, no longer belongs to obscure lore: A wriggly toddler, obsessed with numbers and letters, is already spelling out words—when he isn't intently lining up his toy cars or melting down at loud noises. Perhaps he begins to seem even harder to engage than usual. Or a teacher or relative remarks that he isn't really interacting with other kids. A parent's something-isn't-quite-right feeling intensifies. It is time to turn to, where else, the Internet. Venture beyond Urban Baby and there, awaiting discovery, is a new term that might help explain an avid, and cuddle-averse, code-breaker: "Is my child an autistic savant?" Darold A. Treffert, a soft-spoken Wisconsin psychiatrist in his 80s who has been called the "godfather of savant research," was surprised by how often visitors to his website sent that question to his inbox as the new millennium got under way. Hopes

ILLUSTRATION BY DANIEL GREENFELD

and fears about what a child will grow into, or out of, can take sudden swerves.

An expert consultant on the multi-Oscar-winning *Rain Man* (1988), Treffert had banished the old idiot prefix and helped spread an awareness of a disorienting phenomenon: remarkable gifts emerging in tandem with profound neurological problems—and "without lessons or training," he marveled. In the film, Dustin Hoffman's Raymond Babbitt, fidgety and uncommunicative, could count spilled toothpicks at a glance and multiply big numbers very fast. Neuroscientists and psychologists, though stymied by a sample size too small for rigorous study, were fascinated. Musical gifts (including absolute pitch), artistic flair (generally hyperrealistic), calendrical agility (naming the days of the week on which particular dates fall), computational virtuosity: The startling skills, accompanied by astonishing powers of memory, seemed to be disproportionately associated with autism.

Treffert had a new prefix for those who burst forth with more than "splinter skills." They were "prodigious"—the rarest subcategory of already rare savants, who would count as prodigies even if they had no disability. Soon enough his informal global inventory of prodigious savants could boast a bona-fide American prodigy, a preteen with a reedy voice and an innocently intent Harry Potter face. His name was Matt Savage, and by the time Treffert met him, he had been hailed a "Mozart of jazz." Born in 1992 in Boston and given an autism spectrum diagnosis three years later, Matt emerged as the perfect poster child for the newly capacious vision of savant gifts, not that anyone told him the term. Matt, easily overwhelmed by a clamorous world, loved multiplying large numbers, performing calendrical stunts, amassing facts—the telltale memory-based, repetitive sort of talents that cropped up in roughly 1 in 10 people on the autism spectrum. But his real fervor was directed at jazz. He was soon jamming and composing—precisely that kind of creative and improvisational work that had been presumed out of bounds for savants.

Treffert's unusual club soon had another member, whose mother had found her way to his website. Jacob Barnett was six years younger than Matt. As a toddler in rural Indiana, Jake had retreated into autistic silence, only to re-emerge and surge ahead in math and science, astronomy in particular. He displayed phenomenal powers of recall and, barely out of kindergarten, began discussing Kepler's laws. Jake could also play back tunes and do calendrical computing, his mother discovered before long. Surfing the Internet together, they looked for kids like him. When they came upon other savants, he eagerly displayed similar skills. She called Treffert, who predicted further surprises.

These children were—glaringly, unmistakably—different. And at the turn of the millennium, in a country that for decades had been preoccupied with early extraordinary achievement, the approach to children so incongruously out of step was notably different, too. Their otherness wasn't explained away or played down or defined up, standard impulses among experts and parents busy spotting and spurring on youthful talent in a meritocratic era. Jake's academic leaps thrilled his parents less as a sign that he was speeding ahead than as evidence that he could avoid derailment: Terrified when he had shut down as a toddler, they dreaded that ever happening again. Unlike various prodigy predecessors, Matt was quite obviously not on a fast track to popular renown, or cutting-edge inventions, or vast fortunes (or likely to be swept up in an unanticipated wave of competitive interest, as Bobby Fischer had been). His musical obsessions were hardly trendy—not that the small boy noticed. And his parents didn't much care. Above all, they, like Jake's mother and father, were intent on helping their hard-to-reach child engage somehow.

Propelled by sudden inspiration and rapt concentration, these strange young minds in turn moved parents and mentors to transcend conventionally ambitious dreams and refocus: Look at how the unusual gifts could work wonders now. Their mastery was stunning, yet what these prodigies highlighted was the mystery of inborn talents. Even if the made-for-prime-time saga of uncanny virtuosity and effortless progress wasn't the full story for Matt or Jake, as it surely wasn't, here were gifts that had blossomed so far without competitive pressure. A tidy or speedy script for long-term success wasn't on hand either. The boys and their families—as well as the experts probing for affinities among prodigious savants, "regular" prodigies, and the rest of us—were playing it very much by ear.

There was also a silver lining of sorts.

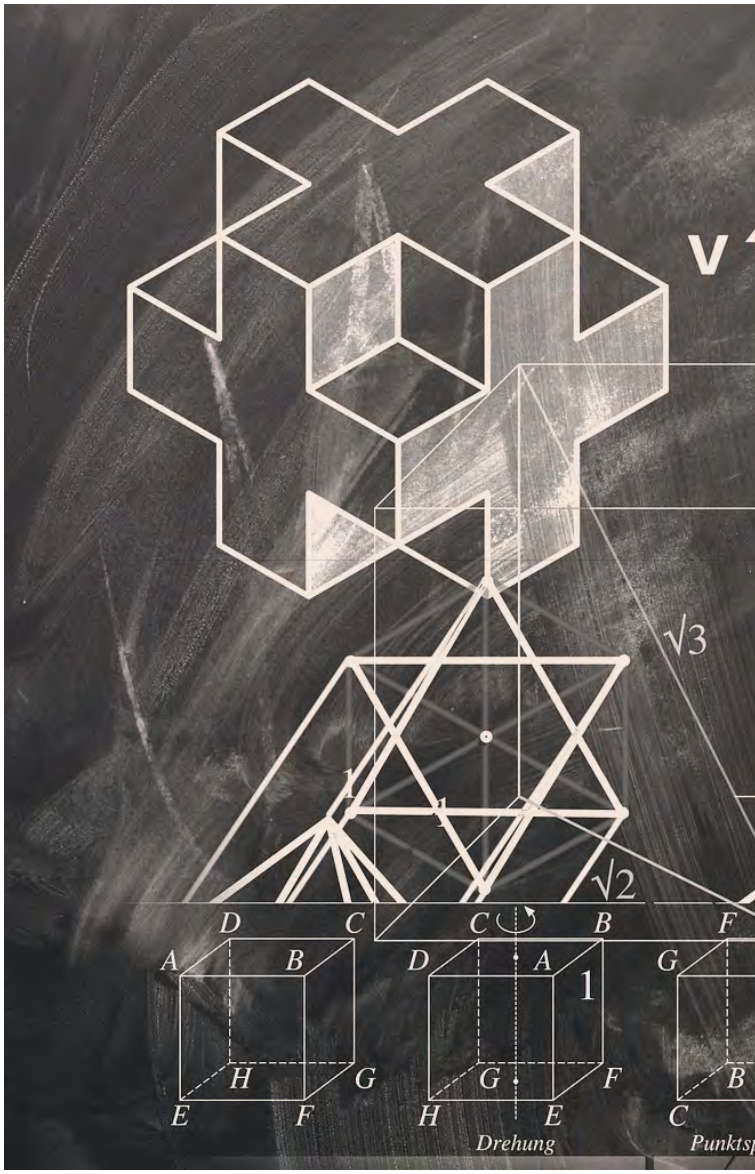
The extreme isolation could be a spur to learning.

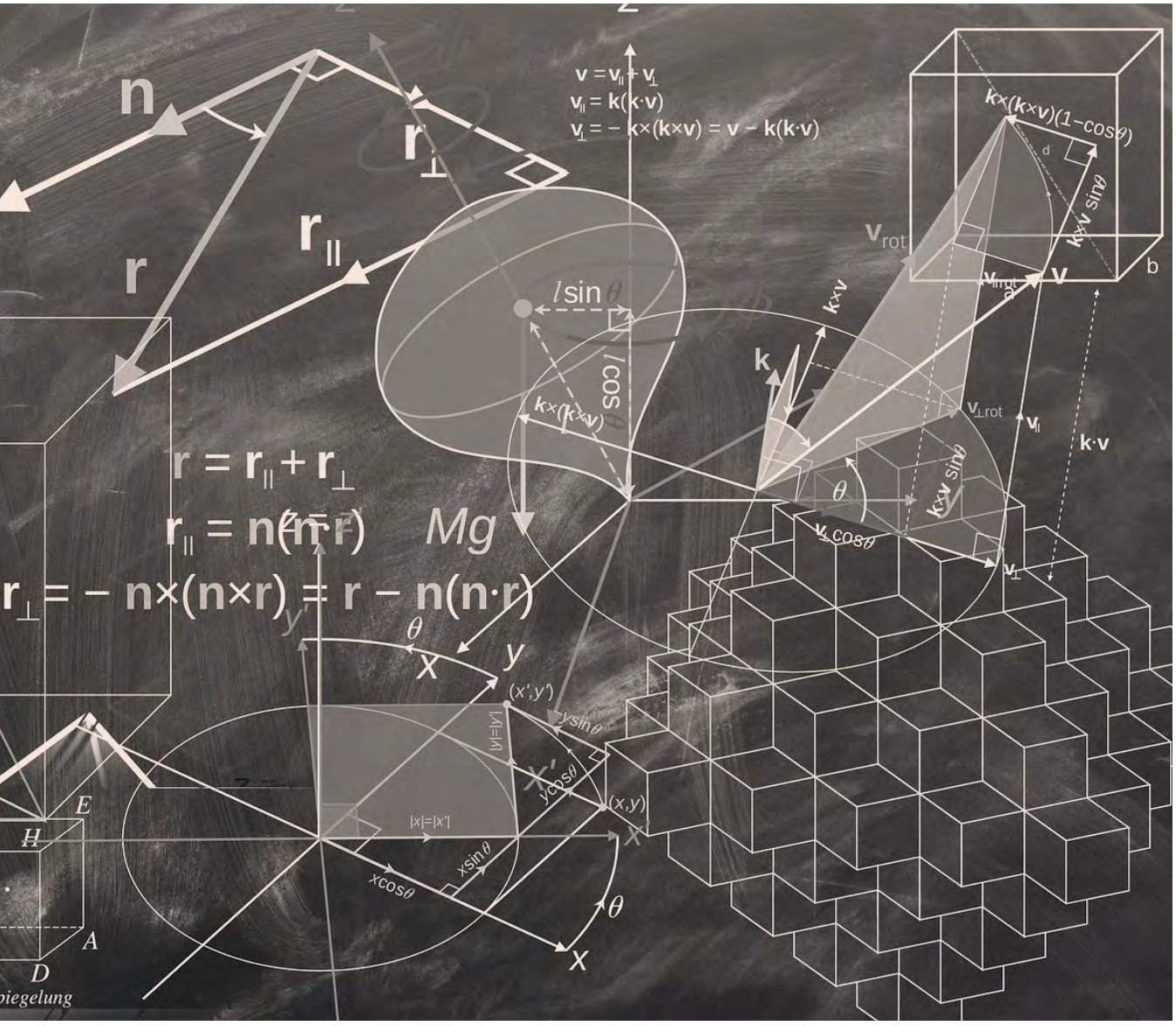
YOU COULD SAY that inside just about every well-rounded young wonder touted in the 20th century there had been a lopsided, often lonely rarity trying to get out. Autistic prodigies at the turn of the millennium succeeded—and then some. The boys invited the kind of awed appraisal that had greeted (and soon grated on) the 19th century's most famous shut-in child, Helen Keller, and her teacher, Annie Sullivan, christened a "miracle worker" by Mark Twain. He also called her Keller's "other half." The pair's emotionally entwined, pedagogically intense alliance was indeed crucial—and would have been impossible without Keller's "soul-sense." That was her phrase for the acute empathy that served as her special radar. Matt Savage and Jake Barnett experienced the opposite: "mind blindness," the inability to extrapolate the mental states of others that is a signature symptom of autism.

Both the boys and the adults on whom they depended could hardly have been more disoriented—which is not to say they were unfocused. Acutely sensitive to stimuli, fixated on details, reliant on strict regimens and repetitive behavior, cut off from conventional expectations: The profile fit Matt and Jake starting very young. A version of it also fit their mothers, caught up in the all-consuming mission of doing their best to deal with children who weren't merely out of step with peers, as prodigies always are. Their sons seemed barely to register others. Yet there was also a silver lining of sorts. The extreme isolation could be a spur to learning, as Annie Sullivan had noted in Helen's case. "She has one advantage over ordinary children, that nothing from without distracts her attention from her studies."

But first comes the challenge—presented by ordinary and extraordinary children alike—of spotting the something within that might direct youthful curiosity and help develop raw capacities. Prodigies generally make that task astonishingly easy, very early. Yet Matt and Jake are testimony to how obscured those inner interests and aptitudes can be, and how difficult—and crucial—tapping into them may prove. Who knows whether they may be developed into an exceptional talent, but they just might serve as a basic conduit to the world. Or could, if not for a catch-22: Autistic children supply at best garbled signals to guide their elders.

Matt was chattering away and reading at 18 months, and counting Cheerios in his high chair. His parents—Diane Savage, then a computer programmer for a company in the Boston area, and her husband, Larry, a chemical engineer who worked in IT at Raytheon—took pride in their precocious son. At the same time, they couldn't ignore Matt's hand-flapping, his failure to make eye contact, his aversion to touch and to all kinds of sounds, even the swishing of windshield wipers. He would throw fits over rituals gone awry. The





PIXABAY

Savages, who in the early 1990s knew next to nothing about autism, felt they had an explanation for their brilliant boy who demanded quiet, except when he wailed at a noisy world: "He's so busy learning things, he can't deal with the sensory side of things was our theory," Diane said. But Matt's brief foray into Montessori preschool—he lasted two days before being "officially expelled," as she put it—tested the theory. Something just wasn't right, and Diane, a woman used to getting results, now needed answers.

With Jake, the discordance was more dramatic, as his mother, Kristine Barnett, chronicled in her 2013 memoir, *The Spark: A Mother's Story of Nurturing, Genius, and Autism*. Before he turned 2 in the spring of 2000, he was a giggly, easygoing toddler who wrestled with his dad and was a wizard with words. He talked early

and recited the alphabet backward and forward. He memorized DVDs (not just in English: He liked switching the language selection). He read along with a CD-ROM of Dr. Seuss. But gradually he ceased to speak or respond. Kristine, who poured her abundant creative energy into directing a lively day care center in their garage, watched him gaze for hours at plaid fabrics and patterns of shadows. He would spin in dizzying circles, stare at his hoard of flash cards, shrink from physical contact. At least he didn't throw fits. Michael, Jake's father and a Target employee, kept saying it was just a phase. But articles about autism were everywhere now, and Kristine's mother, struck by one, dared to suggest they had better find out what was wrong.

For both the Savages and the Barnetts, a diagnosis delivered a reverse epiphany. They got no sudden insight into what their sons desperately wanted to do. Instead, it now hit them how much they, the parents, were going to have to do—and how little they, or perhaps anybody, understood what was happening in those young heads. Her multisyllabic talker, Diane now realized after an evaluation at Boston Children's Hospital, was imitating more than communicating. Churning through books, Matt wasn't following the plots. The experts proposed the then newly minted Asperger's label. Six years later, Kristine received the same verdict when a battery of in-home assessments revealed that along with radically skewed skills, Jake had a super-high IQ. Unaware that Asperger's was on the dreaded autism spectrum, Kristine was briefly buoyed—and then a second evaluation before he turned 3 put him into the "full-blown autism" category.

The maternal approach, at the outset, was lockstep-parenting-according-to-the-experts of a sort that could make the most Ivy League–obsessed overschedulers look like slackers. "We research the hell out of everything. That's our scientific approach," explained Larry, who quit his job to manage the intricate family logistics. (He took up financial investment work from home.) Diane, who left her job as well, immediately turned for advice to the autism crusader then on the cutting edge. The very night she got back from Matt's evaluation at Children's Hospital, Diane called Bernard Rimland, the founder of the Autism Research Institute, not expecting him to pick up. It was late, but he did.

The Savages put Matt on the DAN! (Defeat Autism Now) protocol, the array of dietary strictures and other treatments that Rimland had begun promoting. Matt's sensitivities, his parents felt, quickly improved. He wasn't easy to get through to, but they put his hyperlexia to use: Often unresponsive to verbal directions, Matt couldn't resist reading written notes. He also underwent Auditory Integration Training, another experimental treatment for autism gaining popularity in the early 1990s. And Diane choreographed an intensive weekly regimen of carefully vetted therapy sessions (occupational, physical, speech, behavioral) for him, plus a roster of parent support group meetings and conferences for her.

Every interaction with Matt had an "ulterior motive," she said. Even what looked like downtime at home was hardly a respite. The purpose of their games was to help him overcome social barriers, learn new behaviors, acquire the basic life skills he lacked. But Diane had rewards at the ready, too—math workbooks and puzzles as treats for a boy who could tell her, and did, "My mind is made of math problems." The Savages joined a nearby autism preschool collaborative. Still, Diane was exhausted, and Matt, now 6, seemed to be slipping. Bothered by sounds again, he acted out more.

A half decade later, out in Middle America, the Barnetts were several steps lower on the income ladder than the Savages, and their son was drifting further toward the low-functioning end of the autism spectrum. For Kristine and Michael, state-funded professional services for children with autism were the affordable resource at hand—a special education realm by now more systematized than the cure-focused vanguard at the core of Diane's tailor-made treatment plan. Jake was signed up for the full range of therapy that Indiana's First Steps program offered children with developmental issues until they turned 3. "The calendar on the kitchen wall was so jam-packed that nobody but I could read the microscopic handwriting I used to cram it all in," Kristine noted.

Doing further research, and pestering (her word) therapists who had become friends, Kristine wanted to do more. She and Michael added 40 hours a week of "applied behavior analysis" work with Jake, later shifting to a less drill-oriented and more child-initiated "Floortime" therapy (which was just as time-intensive). And when First Steps services ceased, and a summer

He pulled yarn and wrapped it all around the kitchen.

Instead of a "terrible mess," she was stunned to find he had woven intricate multicolored webs.

loomed before state-funded developmental preschool began, Kristine got even busier. She devised more sensory-rich activities to keep Jake from losing ground, enlisting high school volunteers to help.

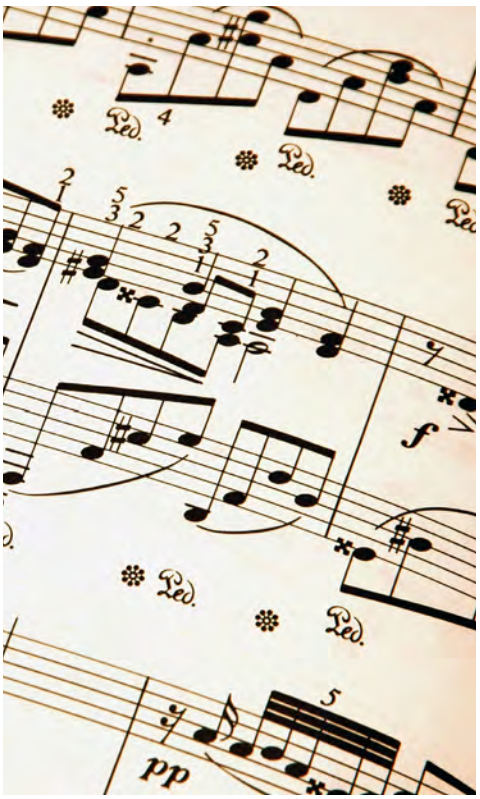
But she could tell Jake wasn't really tuning in, and after starting to communicate by pointing at cards with pictures—a big step—he made little progress. She couldn't help noticing, though, that during the activities he did on his own time (what little there was of it), "his focus was ferocious," and the results could be startling. That summer Jake was obsessed with Kristine's knitting basket. He pulled out yarn and wrapped it all around the kitchen. Instead of a "terrible, tangled mess," she was stunned to find he had woven intricate multicolored webs.

What the two of them needed, it dawned on her, were breaks from the constant work of therapy. Kristine began scooping Jake up, along with a box of Popsicles, for short nighttime outings to a nearby country pasture—plain old childhood fun. He still barely acknowledged her presence, but he was obviously transfixed by the stars, even if he couldn't tell her that. Several months into their "dates," he once actually blurted out a "night-night" at bedtime. So Kristine was crushed as she watched the relaxed boy of those summer moments regress when he began heading off on the bus to spend his days in developmental prekindergarten.

However tirelessly they followed the experts' regimens in the early years, neither Diane nor Kristine was about to settle for mere repetitive structure and drills. Their best guides, as they did their utmost not to forget, were the boys right in front of them—each stuck at a difficult point. Matt, struggling with sensory overload at 6, and Jake, who seemed miles from being kindergarten-ready: Both had their mothers feeling stymied, discouraged by the narrow emphasis on the basic skills their boys lacked. Their maternal reflex, which helped them forge on, was to shift the focus to gifts they were sure lurked within.

"I always believed that even when he was hard to reach, there was a shining star in there," Diane later told a CNN interviewer eager to hear about Matt. Her goal: "We just had to find a way to get to it." The rhetoric of unshakable faith in an inner light ran through Kristine's book, too, an amped-up echo of Annie Sullivan's

insistence on kindling Helen Keller's interests, bucking straitlaced pedagogy in the process. "I knew my child better than any expert could," Kristine wrote. "And I saw a spark in Jake. Some days, true, there was only the faintest glimmer." Framed this way, manic helicoptering became something more like heroic liberating. The top-down micromanaging was supplanted, or at any rate richly supplemented, by bottom-up empowering. Where lore had it that Helen Keller suddenly awoke to the possibilities of language as her teacher spelled into her hand at the water pump, the child-driven drama with these boys was different: Discovering and encouraging their special language was a quest that kept adults on their toes.



When he was 6, math-minded Matt stumbled on his power to make very gratifying sense of a new realm of patterns—thanks to more active help from his mother than she generally took credit for. A second round of Auditory Integration Training that year did more than make sounds bearable for Matt. Diane and Larry, upstairs in their Sudbury house, were stunned to hear him downstairs playing "London Bridge" and other tunes on a rainbow-keyed Little Tykes xylophone piano that came with color-coded music. Now Diane showed him middle C on their big piano, pointed out how the Little Tyke music sheets matched up with the keys, and explained the way octaves worked. For Matt, whose fascination with numbers and ratios had lately spawned an obsession with roller coasters (he loved reciting their speeds and other specs), it all made sense. He quickly figured out the piano's 88-note language of sound.

Diane once again hurried to the phone. A local piano teacher who came highly recommended (and who, Diane said wryly, sighed when she heard yet another parent touting a gifted child) agreed to meet Matt. His perfect pitch, sight-reading skill, ability to play back what he heard, and astonishing memory—plus his restless energy—left her in no doubt: Here was a "special situation," in Diane's words. As Matt careened between piano and couch, knocking over plants en route, he made remarkable—if unruly—progress in their weekly lessons. When he chafed at being told to play the notes on the page, rather than the ones he thought sounded best, his no-nonsense teacher was firm. Classical pianists, she said, stick with scores. Jazz pianists, his ever responsive mother mentioned, get to improvise. As Matt later remembered it, his parents at some point played Miles Davis's *Kind of Blue* for him, and it made a big impression.

As Diane liked to tell the story, an event at a crafts fair in Maine the following year made a big impression on them. The family strolled past a jazz band warming up in a tent, and Matt, then 7, yanked free of her grasp. He climbed onto the piano bench, asking to play, and when the surprised sax player proposed a blues tune in the key of B-flat, Matt proceeded to chime right in. In truth, as Diane had "to admit sheepishly," she was the one who had asked whether the band could play a song with Matt. He would never have reached out that way, and she was just hoping to fend off a tantrum as she tried to extricate him from the tent. But she wasn't embellishing, she stressed, in saying he had never played anything like that before. The sax player ran after them, urging jazz lessons for Matt. Diane, as usual, got right on the phone. This time she called the precollege program at the New England Conservatory. At the audition, held two weeks later,

ARIEL SCHROTTE / SHUTTERSTOCK

Diane said Matt astonished the faculty.

Faced with a truly boxed-in boy, Kristine emphasized that she was no mere behind-the-scenes facilitator in the unfolding of Jake's powers. She was a "fighter," ready to do battle against a blinkered educational system prone to underestimate children's potential. If a boastful tone crept in, and it did, Kristine's immodest confidence ("I came to see my maternal intuition as a compass pointing true north") and her crusading gumption ("the over-the-top 'muchness' of my schemes was a big part of the way I worked") also drove her crucial decision. She pulled Jake out of state-funded developmental preschool, convinced he was shutting down out of boredom. The boy who clutched his alphabet flash cards (which his teachers told Kristine not to let him bring to school) wanted to learn, her intuition told her. Never mind grand expectations, her hope was to help pave his way into mainstream kindergarten.

At home, she now carved out time for activities Jake loved and was great at (like puzzles), not just for practice in what he couldn't do (like sit still next to another child)—and at 3 he began talking again. That didn't mean conversing. Still, Kristine was listening closely to his litanies and realized he wasn't just reciting numbers but adding them, as well as reading and remembering everything. And she saw that Jake now constantly dragged around a college astronomy textbook she had bought at the local Barnes & Noble when she had found him sitting on the floor glued to it. But Kristine couldn't forget about those social skills if he was going to have a shot at kindergarten. So she ended up running "a highly unorthodox kindergarten boot camp" for autistic kids, welcoming, rather than squelching, a common symptom: intense and persistent interests, in Jake's case, astronomy.

A special program at the planetarium on the campus of nearby Butler University was the Barnetts' turning point. A rapt Jake stunned the audience with an astute question about Mars' moons, and on the drive home, couldn't stop talking about the solar system. Jake "hadn't been missing after all," she realized, just because he was unreachable. Unhindered, he had been busy working: His repetitive behavior, much as some autism researchers have speculated, reflected detail-oriented curiosity rather than being merely a self-soothing habit. "Rage to master" was a relevant phrase coined by another psychologist, Ellen Winner, who concluded that a fiercely self-propelled drive was what set a true prodigy apart from a super-industrious high-achiever. "Nobody was telling Jake how to learn," Kristine wrote, "because nobody thought he could. In that way, autism had given Jake a bizarre gift."

Prodigies of all kinds deliver surprises, even as they also promise to reveal talent development insights for the rest of us. If anything, these boys—precisely by flouting the far-reaching hopes and plans of adults from the start—supply a perspective we could really use. All too often, the impulse to herald children's gifts risks inspiring swelled heads and raising sky-high hopes that are likely to be disappointed. But adopt the viewpoint of the hypersensitive and remote child, and of the family hoping to help him feel less overwhelmed by the world, and the impulse to champion a child's singularity becomes an opportunity—and an invitation to humility. Jake and Matt got the benefit of having grown-ups in their lives who, however determined they were to front-load intensive training for their children, quickly discovered the limits of being in a goal-focused hurry. If the boys' gifts could help them connect with the world as they grew, that was progress. And if the most basic lesson they and their parents and mentors learned from one another was undaunted curiosity about what might lie in store, that marked a real advance, too.

ANN HULBERT is the author of *Raising America: Experts, Parents, and a Century of Advice About Children* and *The Interior Castle: The Life and Art of Jean Stafford*. Her articles and reviews have appeared in many publications, including *The New York Times Book Review*, *The New York Review of Books*, and *The Atlantic*, where she is the literary editor.

From *Off the Charts: The Hidden Lives and Lessons of American Child Prodigies* by Ann Hulbert (Knopf, Jan. 9, 2018).

57

THERE'S AN EASY NARRATIVE about the fracturing of modern community: Falling marriage rates produce more single-person households, digital technologies disrupt in-person interactions, and identity politics cast one group against another. Our centuries-long devotion to the idea of the individual, it seems, has gone too far.

But, as sociologist Gary Marx observed 20 years ago, many of these trends are met by counter-trends that strengthen social cohesion rather than weaken it: We attend more cultural events, spend more nights out socializing, and communicate more with each other. In other words, we're doing what we've always done: adapt.

Rather than eroding our communities, it might be more accurate to say we're building a dialectic around them.

Welcome to "Communities."

—MS

"All resilient things start local. To find inherent value and stability digital currencies need to ground themselves somewhere. They need to go local."

FOUAD KHAN
"Why New York City Needs Its Own Cryptocurrency" p.60

Communities

UNCOMMON WISDOM


TATI
NOVI
EBORACI

Why New York City Needs Its Own Cryptocurrency

The case for making money local again

BY FOUAD KHAN

MONEY USED TO BE LOCAL. The first non-precious metal coins emerged as a natural consequence of trade, and were seldom accepted as currency outside the city-state on the Grecian coast that minted them. Then nation-states emerged and central banking was invented as an institution. Fiat currencies were deigned into circulation and the connection between money and place was mostly lost. Today, a dollar printed in West Point is the same dollar wherever it is found, whether it's Dubuque or Dubai. It derives its value from the law of the United States and that law has no physical home. The United States of America, like all other countries, is a polygon on a map, a theoretical construct, a policy document.

As the dust settles on the haboob that cryptocurrencies have become over the last year or so and we try to find things of lasting value from the wreckage, we should keep in mind this missing piece of the puzzle: All resilient things start local. To find inherent value and stability digital currencies need to ground themselves somewhere. They need to go local. A theoretical construct is no longer enough. Digital currencies need something more tangible than just value by decree. They need a physical place where people can go and where the token will always be valued and the debts will always be paid. They need a city.

From the city's perspective it makes perfect sense. Most cities struggle with securing the finances they need. Cities are taut systems operating at the edges of possibility, constantly optimizing the resources that are available to them. Consider New York, one of the richest cities in the world, with an economy larger than Mexico's. Despite its wealth, it has attracted much negative recent attention for having a drastically underfunded public transport system. Something like $100 billion is needed to fix the New York subway, and nobody knows where that money is going to come from. Almost every city has a laundry list of essential projects that are in dire need of cash. Launching a digital currency for a city could effectively crowdfund these projects.

Here's how it would work. New York simply

ILLUSTRATION BY FRANCESCO IZZO

announces that starting on a given day, a digital currency, let's call it NYCTokens, can be purchased from subway station kiosks. These would be redeemable toward civic services inside the city, like subway rides, health clinics, utility bills, city taxes, hospital or school bills—basically any services that the city provides directly, or for which the city could work out a mutually beneficial arrangement with a third party. The city would also publish an app that would allow anyone to send or receive tokens. However, new tokens would have to be purchased in person at a physical location. The city wouldn't sell the tokens online or let a third party set up an exchange. By blocking mass-scale transactions in this manner, scalping and mass speculative trading would be discouraged.

The most important question is where NYCTokens derive their value. What will they be "pegged" to and how will the important problem of cryptocurrency volatility be solved?

There's a very neat two-word answer to all these questions.

Property values.

The value of each NYCToken is pegged to property values. One NYCToken, for example, could be made equal to the market value of 1 square centimeter of New York real estate. At a current costs per square foot of say $1,500, that works out to about $1.60 per token. The city maintains an up-to-date ledger of all property sales, and as the average value of property changes, the value of the NYCToken rises or falls. The number of NYCTokens in circulation corresponds exactly to the total covered area of the city and more tokens will be brought into circulation if and only if the city's real estate area increases through vertical or horizontal development. Increases in token price represent an increase in real estate value, which can be considered a weak proxy for standard of living, and increases in token number represent city growth.

Digital currencies need a physical place where the token will always be valued and the debts will always be paid.

By buying tokens citizens get the opportunity to invest their surplus income in an asset that is a store of value, an investment with the potential for real appreciation, and a currency that can be used to buy urban services. Instead of adding dollars to her subway card, for example, a city resident could add NYCTokens. The next day, she could spend her tokens to gain entry to the subway system. But if she hangs on to her tokens and they double in value, she could then purchase two subway rides for the same number of tokens. The growing prosperity of the city translates directly into an improved quality of life for its residents, through effectively cheaper urban services.

The prospect of rising token values will attract many citizens to invest in tokens, especially in big

UNTETHERED Without any grounding in local economies, cryptocurrencies like bitcoin have exhibited great volatility.

cities like New York where property prices are considered a safe bet. The tokens will also attract some investment money from parties who are unlikely to ever trade them for urban services: hedge funds, banks, individual investors, and non-residents. An informal economy will emerge out of people replacing some of their cash transactions with the token transactions on the app. In due time taxing these transactions could also become a source of revenue for the city. In principle, the price of tokens on this informal market may rise above the price supported by the city. But it is unlikely to fall below the price supported by the city, since tokens can always be traded in for real services at the official price.

The net effect of both individual and institutional interest in tokens will combine to produce the same phenomenon: a fresh stream of critical capital for the city to invest in urban development projects. Having their money directly invested in the city will inspire citizens to get more involved in development and political decision making. And since the money raised will be invested back into the city in a way that raises property values (like subway construction projects), tokens would create a self-reinforcing prosperity loop.

There will be complications, of course. A big one will be the legality of a city-based currency. In many countries, cities don't have the legal authority to issue their own currencies. That, however, is a problem that can be easily solved. Just make sure not to call your new digital object a currency, or money, or coin, or any variants thereof. Make it a subway ride credit. Or school lunch credit, electricity credit, gas credit. Heck cut a deal with Uber and call it Uber credit. The point is that there are many other tokens of value in circulation inside cities that can all stand for "unit of value."

Another problem to solve would be the volatility brought about by secondary speculative trading. This is naturally tamped by the fact that the token can only be redeemed through urban services. The liquidity of the token for the speculative investor will be naturally limited. Only people willing to bet on the city and not just on the currency will make large long-term investments.

It should be noted that a number of countries, including Saudi Arabia, UAE, Venezuela, and even city-states like Dubai, have already started considering their own cryptocurrencies. But these efforts do not peg their digital currencies to the cost of local services. A cryptocurrency backed entirely by urban fiat has the potential for being the worst of both worlds: It combines an arbitrary, centralized valuation with the potential volatility of cryptocurrencies. Similarly, combining the blockchain with centralized control makes no sense. The solution to currencies dissociated from the value they are supposed to represent is not another floating abstraction made even more volatile by a publicly distributed ledger, but a re-grounding and return to intrinsic value.

Money has traveled around the world in the last 2,000 years and almost freed itself from grounded constructs and borders. Some say this is the root of all evil: Capital is free to move, while individuals are tied up in innumerable layers of bondage from national laws to company policies. In the age of digital we've come to believe that new solutions have to be universal, but that need not always be true. In many ways modern interest-based money has been the prodigal son of our civilization. It has fueled exponential growth, but it has also become too abstract a construct to control.

Maybe it's time for money to come back home.

Fouad Khan has a Ph.D. in urban development science and policy and has worked for the World Bank, UN, and WWF among others in the past. He is currently an associate editor at *Springer Nature* and tweets at *@fouadmkhan*.

GOOGLE FINANCE

Waiting for the Robot Rembrandt

What needs to happen for artificial intelligence to make fine art

BY HIDEKI NAKAZAWA

THE CELLIST JAN VOGLER famously claimed that art is what makes us human. But what if machines start making art, too?

Below is an example of a piece of art made by an artificial intelligence (AI).

On the right side of the picture is a computer running AI that has been trained with images of graffiti. It controls a plotting head that sprays water onto concrete blocks, on the left. The resulting patterns are a form of computer-generated art.

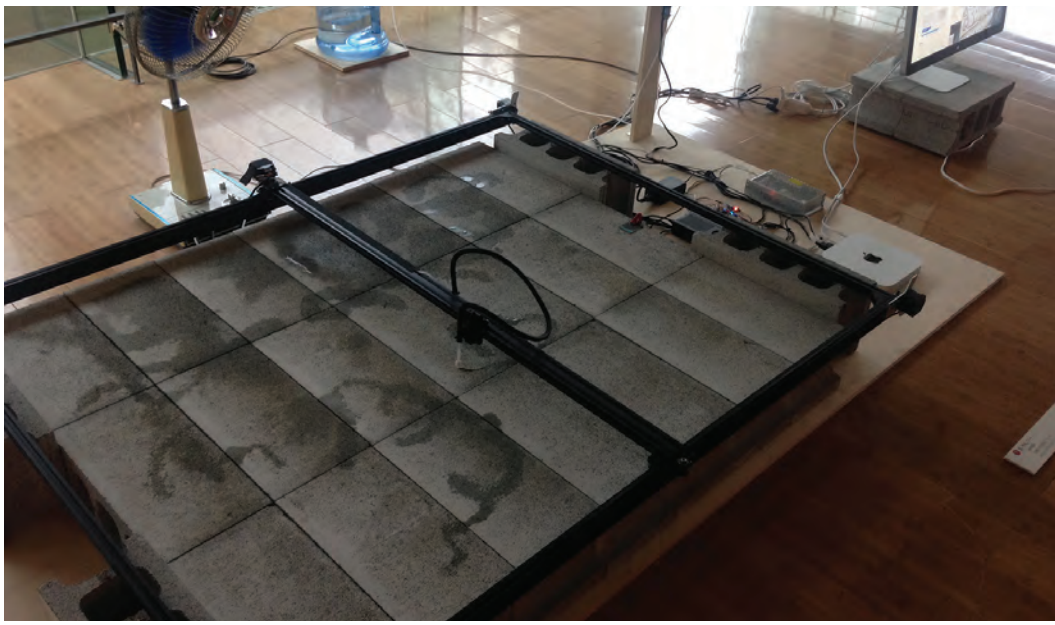
Is this fine art in the true sense? If it is, we would need to confront the possibility that some part of our humanity—the part that Vogler was referring to—has been captured by machines. The fact is, however, that while the output of the machine may be artistic, it is not making fine art.

When art is made to satisfy the needs of a third party—in this case, the computer programmer employed by the artist—it is illustration or commercial art, not fine art. If fine art is ever to be made by AI, it must be its own: produced by machines autonomously, independently, and actively for the machine's own sake and with the machine's own aesthetics. Only in that case would the art not be a passive product of human creation.

On January 8 of this year, the Artificial Intelligence Art and Aesthetics Exhibition concluded its run at the Okinawa Institute of Science and Technology Graduate University (OIST) in Okinawa, Japan. The focus of the exhibition was this concept of true, artificially intelligent fine art. The only problem for the exhibitions curators (including myself) was that art in this category does not yet exist.

To get around this awkward fact, the exhibition shows were divided into four categories: (1) Human Art / Human Aesthetics, (2) Human Art / Machine Aesthetics, (3) Machine Art / Human Aesthetics, and (4) Machine Art / Machine Aesthetics. Category 1 contained a collection of conventional human art, from the Renaissance on. Categories 2 and 3 presented a collection of hybrid man-machine art, as their names imply. Category 4, on the other hand, had no machine-made art, because none exists that also reflects machine aesthetics. The category was a useful placeholder—and, as we'll learn, it was not entirely empty.

Each category teaches us its own lessons. The art in Category 1 shows the historical transformation of aesthetics away from a God's eye perspective, and toward a human perspective. The mostly 20th-century systemic art in Category 2, including minimalism, serial music, and visual poetry, is characterized by the use of rules or mathematical forms. Systemic art can be considered to have been kick-started by the Eiffel Tower in



A BIT OF ART A computer trained with images of graffiti produces its own art by spraying water onto concrete. The exhibit, titled *About a Theory of "Graffiti"*, was created by the artist yango2 and shown at the Artificial Intelligence Art and Aesthetics Exhibition in Okinawa this year.

LEAD IMAGE PHOTO COLLAGE CREDITS: B.S.P.I. / GETTY IMAGES; VVOE / SHUTTERSTOCK
THIS PAGE: COURTESY OF THE ARTIFICIAL INTELLIGENCE ART AND AESTHETICS RESEARCH GROUP

1889. The tower's construction was opposed by many famous artists, including the painter William Adolphe Bouguereau and the novelist Guy de Maupassant, because they viewed its plain appearance and machine-calculated design as a hideous denial of human aesthetics. The fact that the Eiffel Tower looks beautiful to most of us today is the central lesson of Category 2: Our aesthetic sense can be changed by mathematics and machines. Category 3 contains a kind of so-called media art, produced by machines and AI, showing us that even as a passive product of human creation modern AI is capable of producing objects of beauty.

Together, the first three categories of the exhibition describe an incomplete arc. We see the birth of the human author, and the beginnings of the AI author. But will a true artificial artist ever exist? Can we expect that aesthetics will one day be generated entirely from within the machine world, without any human-led design? This question was at the center of the exhibition: Will AI ever have its own aesthetic autonomy?

Will a true artificial artist ever exist?

A BEAUTIFUL DREAM This series, called "Deep Rembrandt," was displayed in Category 3, Machine Art / Human Aesthetics. It was generated with Google's Deep Dream AI software.

IMAGES ON BOTH PAGES: COURTESY OF THE ARTIFICIAL INTELLIGENCE ART AND AESTHETICS RESEARCH GROUP

PLATO ARGUED THAT "the true, the good, and the beautiful" are all things that have value in themselves. Beauty has a value in its own right, not because it serves some other purpose. We do good for its own sake, and so on. In order for a machine to make its own fine art, it needs to satisfy Plato's dictum, and create without any utilitarian purpose. The open question is whether machines will ever be able to do so.

One reason to be optimistic is that humans are not the only creatures capable of creation without utility. For example, given drawing materials, chimpanzees have been observed to produce drawings for the sheer pleasure of it. In fact, the Okinawa exhibition includes drawings by five chimpanzees and a bonobo owned by Tetsuro Matsuzawa, a professor at Kyoto University—and all are classified into Category (4), "Machine Art / Machine Aesthetics," to remind us of what is possible. If the animals had made drawings in return for bananas, we wouldn't have included them in that category, because the art would not been created for its own sake.

For AI to get to where chimpanzees are, two steps are needed. First, AI must be able to generate its own goals. The goals of today's AI are designed by human programmers, who write so-called evaluation functions to calculate how well or poorly an algorithm is doing at any given time. The first piece of machine-made art that qualifies for category 4 will need to be able to write its own evaluation functions.

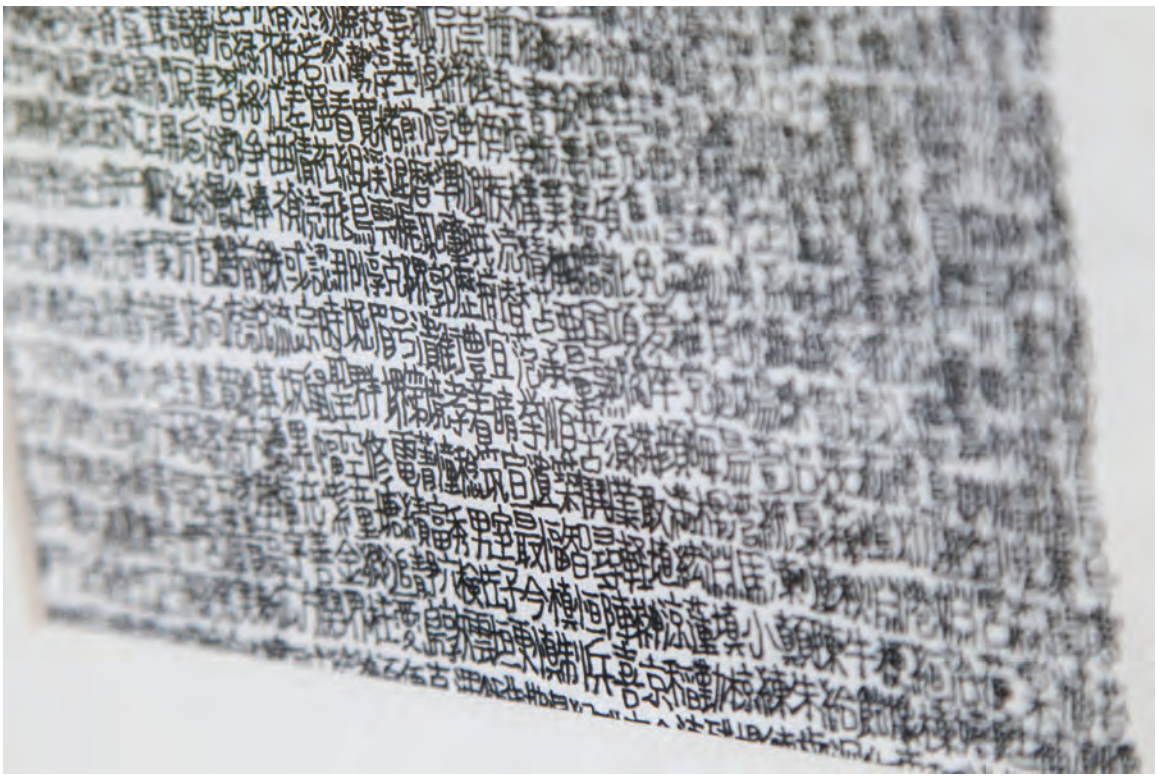
Not only is this possible, it has already been achieved. In fact, if you visited our exhibition in Okinawa earlier this year, you could see it in action. Kenji Doya, a professor at OIST's Neural Computation Unit, and his Smartphone Robot Development Team staged an experiment called "Can Robots Find Their Own Goals?" They placed a collection of robots made from smartphones on wheels into a common area. The robots were able to roam freely, find their own place to charge, and exchange programs by scanning each other's QR codes. Charging was an analogue to eating, and exchanging programs an analogue to reproducing.

DON'T BREAK THE RULES Work by Mika Kusakari and Hideki Nakazawa was included in Category 2, "Human Art / Machine Aesthetics." The art in this category was characterized by the use of rules or mathematical forms.

Robots who didn't charge stopped running, and those who did not exchange programs didn't pass their "DNA" on to the following generation. Over time, the robots began to choose their own goals: Some stopped charging to chase other robots, for example, a behavior they were not programmed to exhibit. The results of this and other experiments have convinced Doya that robots can indeed make up their own goals.

The second step necessary for AI to produce fine art is that it be able to elevate secondary goals—those goals that exist only to serve its primary goal—into primary goals themselves. Suppose, for example, the primary goal of an organism or a machine is to breed. To have sex is a method to breed, so having sex is a sub-goal. To attract a partner is a method to have sex, which can be seen as a sub-sub-goal. To be beautiful is a method to attract a partner, which can be seen as a sub-sub-sub-goal, and so on. But for humans, sex and the beauty of a partner have gained value in their own right. Just as sex for sex's sake can become valuable, so

When AI starts making fine art, will we recognize it?



COURTESY OF WAKATAKE SOCIAL WELFARE CORPORATION, MASARU KAIDO AND ARTIFICIAL INTELLIGENCE ART AND AESTHETICS RESEARCH GROUP

INNER WORLD Part of "Untitled" by the artist Moriya Kishaba. Kishaba, who suffers from autism, tiled a page with Chinese characters in an order that does not make sentences.

can art for art's sake. When an AI has chosen its own goals, and then begun to pursue them for their own sake, it will be on the road to making its own fine art.

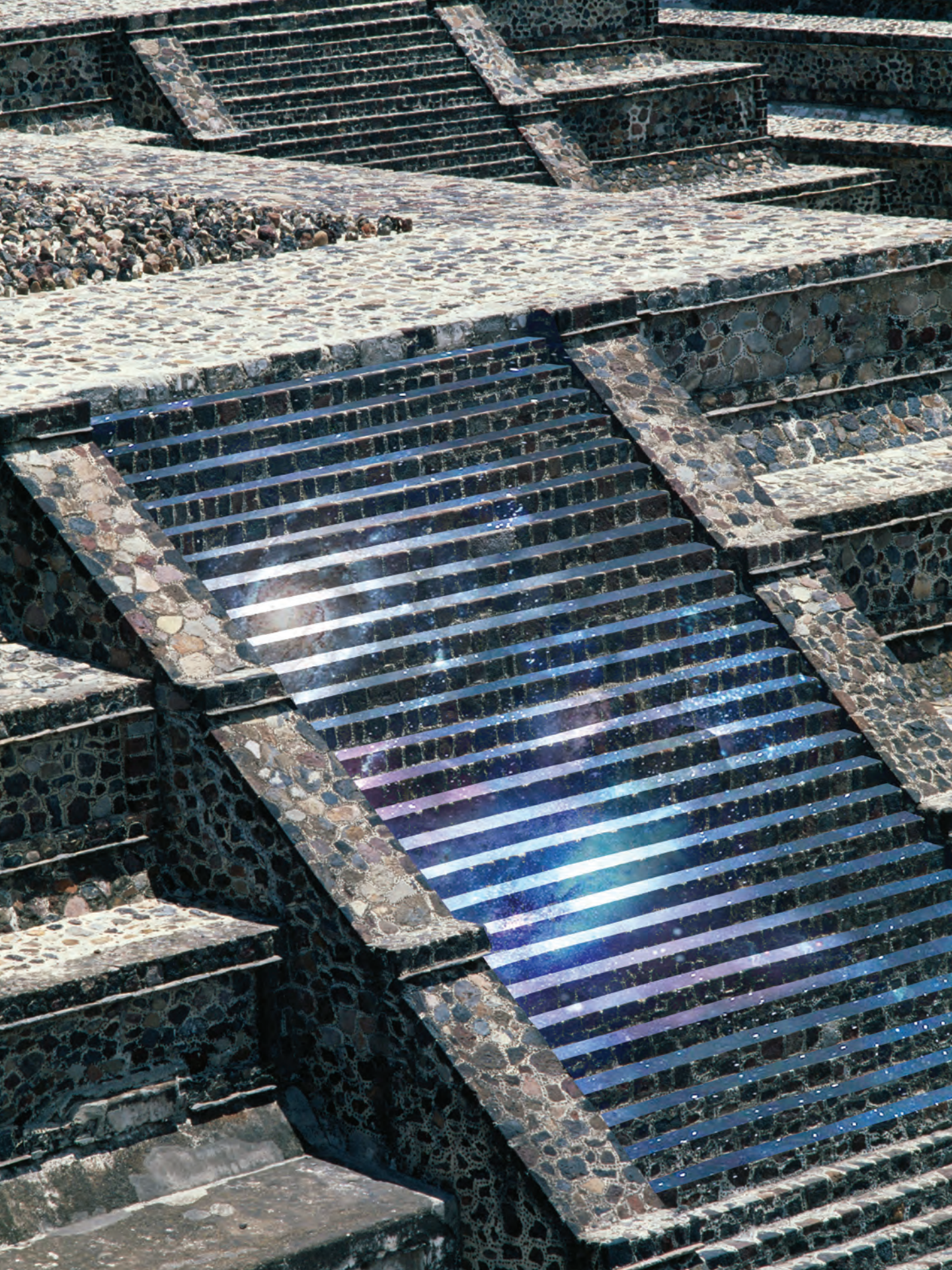
When AI starts making fine art, will we recognize it? We can teach AI our own art history as a way of encouraging output that we will recognize and enjoy. On the other hand, untrained AI will be more likely to produce something starkly original and even unrecognizable, after the manner of so-called Outsider Art or Art Brut. While we cannot divine the internal aesthetic sense of the autistic artist Moriya Kishaba, one of our category-2 exhibitors, many people find his tilings of tiny Chinese characters strangely beautiful. The future of AI art is analogous to a world full of artists like Moriya before they were discovered.

True AI fine art will be both painfully boring and highly stimulating, and that will represent progress. Beauty, after all, cannot be quantified, and the very act of questioning the definition of aesthetics moves all art forward—something we've seen over and over again in the history of human-made art. The realization of AI will bring new dimensions to these questions. It will also be a triumph of materialism, further eroding the specialness of the human species and unveiling a world that has neither mystery nor God in which humans are merely machines made of inanimate materials. If we are right, it will also bring a new generation of artists, and with them, new Eiffel towers beyond our wildest imagination.

Hideki Nakazawa is a Japanese artist born in 1963. His activities include "Silly CG" in the 1990s, "Method Art" in the 2000s, and the publication of books, including *Art History: Japan 1945-2014*. He is also a juror of the Japan Media Arts Festival, and the representative and founder of Artificial Intelligence Art and Aesthetics Research Group.

COURTESY OF THE PRIMATE RESEARCH INSTITUTE AT KYOTO UNIVERSITY AND THE ARTIFICIAL INTELLIGENCE ART AND AESTHETICS RESEARCH GROUP

A STAND-IN Artwork by chimpanzees and bonobos was exhibited in Category 4, Machine Art / Machine Aesthetics.



The City at the Center of the Cosmos

Robots and lasers are uncovering an ancient, sacred geography

BY BRIAN FAGAN

SOME 48 KILOMETERS NORTH of Mexico City, in the Basin of Mexico, towers the Pyramid of the Sun at Teotihuacán. This massive 71-meter high structure makes you feel like a speck of dust in the presence of the gods. And that is exactly what the builders intended. Those who dwelt at Teotihuacán lived at the heart of a vast sacred landscape. The city itself covered more than 21 square kilometers, and it dominated the basin and the surrounding highlands. By 100 A.D., at least 80,000 people lived there. And between 200 and 750 A.D., Teotihuacán's population swelled to more than 150,000. At the time, it was as big as all but the largest cities of China and the Middle East.

Archaeologists have worked there for nearly a century. They've learned that Teotihuacán was a vast symbolic landscape of artificial mountains, foothills, caves, and open spaces that replicated the spiritual world. Over a period of more than eight centuries, the Teotihuacános built 600 pyramids, 500 workshop areas, a huge marketplace, 2,000 apartment complexes, and several plazas.

At some point, the city's rulers decided to rebuild much of the city. They constructed standardized, walled residential compounds, probably to replace crowded urban areas. Some of these housed artisans and their workshops. Others were military quarters. Foreigners from the Valley of Oaxaca and lowland Veracruz on the coast of the Gulf of Mexico lived in their own neighborhoods, which are identified by distinctive pottery styles.

Everything followed a grid plan, with the streets all running at right angles to one another. Bisecting the city in a north–south direction was a wide avenue, known ever since the Spanish Conquest as the Avenue of the Dead.

The great Pyramids of the Sun and the Moon dominate the avenue's north end. Between 150 and 325 A.D., the city's rulers remodeled the Pyramid of the Sun into its present form, enlarged the Pyramid of the Moon and extended the Avenue of the Dead more than a mile southward to include the Ciudadela—the city's new political and religious center. Until recently, not much was known about this impressive structure. Then in 2003, the National Institute of Anthropology and History in Mexico City embarked on an ambitious, long-term program to investigate and preserve the

PHOTO COLLAGE: DE AGOSTINI / ARCHIVIO J. LANGE / GETTY IMAGES; PIXABAY

COSMOLOGY AS GEOGRAPHY A view from the Pyramid of the Moon toward the Pyramid of the Sun.

DEA / ARCHIVIO J. LANGE / CONTRIBUTOR / GETTY IMAGES

Ciudadela temples. The project continues to this day, and in recent years there have been some spectacular discoveries.

The Ciudadela complex is enormous, with high walls and a large courtyard. As many as 100,000 people could gather within the enclosed space for major public ceremonies. The Temple of Quetzalcoatl, the ancient feathered serpent god of Central American civilization, lies within the enclosure, facing the open space. This is a six-level stepped pyramid with a huge stairway running up it, the steps of which form small terraces. Heads of feathered serpents and a snake-like creature, perhaps a war serpent, decorate the faces of these terraces. Reliefs of the feathered serpent also appear under each row of heads, together with a depiction of water. The entire temple was painted blue and carved seashells provided decoration. What the color and the heads and other decorations signified is unknown, but it seems possible that they represented the cosmos (the universe) at the time of creation—a calm ocean.

The excavators started from scratch, working on a temple that had been badly damaged, partly by rain and high groundwater levels, and partly by large numbers of tourists. In 2004, the World Monuments Fund provided money and technical assistance for the

Chávez and his colleagues were the first people to enter the tunnel for 1,800 years.

conservation of this unique structure.

Excavations by Mexican archaeologists in the large plaza beside the Temple of Quetzalcoatl uncovered the remains of several structures that by 200 A.D. had been built on what was originally farmland. These had formed the first religious complex. One of the structures was more than 120 meters long and may have served as a court for ceremonial ball games (an ancient ritual that could include the sacrifice of the losers). The architects of Quetzalcoatl's temple destroyed these buildings when they erected the Ciudadela in its present form.

The open space in front of the temple in the Ciudadela was designed to be flooded with water to form a reflective surface. It was a kind of "water mirror," a symbolic reflection of the calm sea that existed before the creation of the world and humans. According to ancient origin myths, a Sacred Mountain is said to have risen from this watery mass at the beginning of time. All this suggests that the Ciudadela was the setting for rituals in which myths about the creation of the world were re-enacted.

Heavy rains in 2003 revealed a depression and a deep hole in the ground in front of the steps of the Quetzalcoatl temple platform. Now, after years of work, archaeologists explored under the temple for the first time. One—Sergio Gómez Chávez—was lowered by rope through the small opening. He reached solid ground almost 14 meters down and found an underground tunnel leading east toward the Temple of the Feathered Serpent and west toward the center of the great plaza. The tunnel was mostly filled with earth and carved stone blocks, put there by the Teotihuacános.

To clear and explore the underground passageway required careful planning. In 2004, 2005, and 2010, before they went underground, Chávez and his colleagues used ground-penetrating radar to plot the passage from the surface. This suggested that the tunnel was between 100 and 120 meters long, with the eastern end at the center of the Temple of the Feathered Serpent. The radar plots hinted at a large chamber in the middle of the tunnel and an even larger one at the eastern end. They also provided a way of planning the underground exploration.

The investigation was based on a series of carefully thought-out assumptions. First, the researchers assumed that Teotihuacán was a replica of its inhabitants' vision of the universe, with three levels formed by the gods—the heavens, the earth, and the underworld. The horizontal plane represented north, east, south,

and west. And the corners of the plane were the corners of the world.

Second, the excavators assumed that the Temple of the Feathered Serpent symbolized the Sacred Mountain of the creation, thought to have emerged from the calm sea at the beginning of time. The temple stood on a sacred spot, the center of the world. Here you could communicate with the different layers of the cosmos.

Third, they assumed that a sacred cave, thought to lie below the Sacred Mountain, was the place of entry into the underworld. This was inhabited by the gods and by the creative forces that maintained the cosmos. The tunnel, which was partly explored by Chávez with radar, was a symbolic representation of this underworld. According to ancient cosmology (study of the universe), the underworld had its own sacred geography.

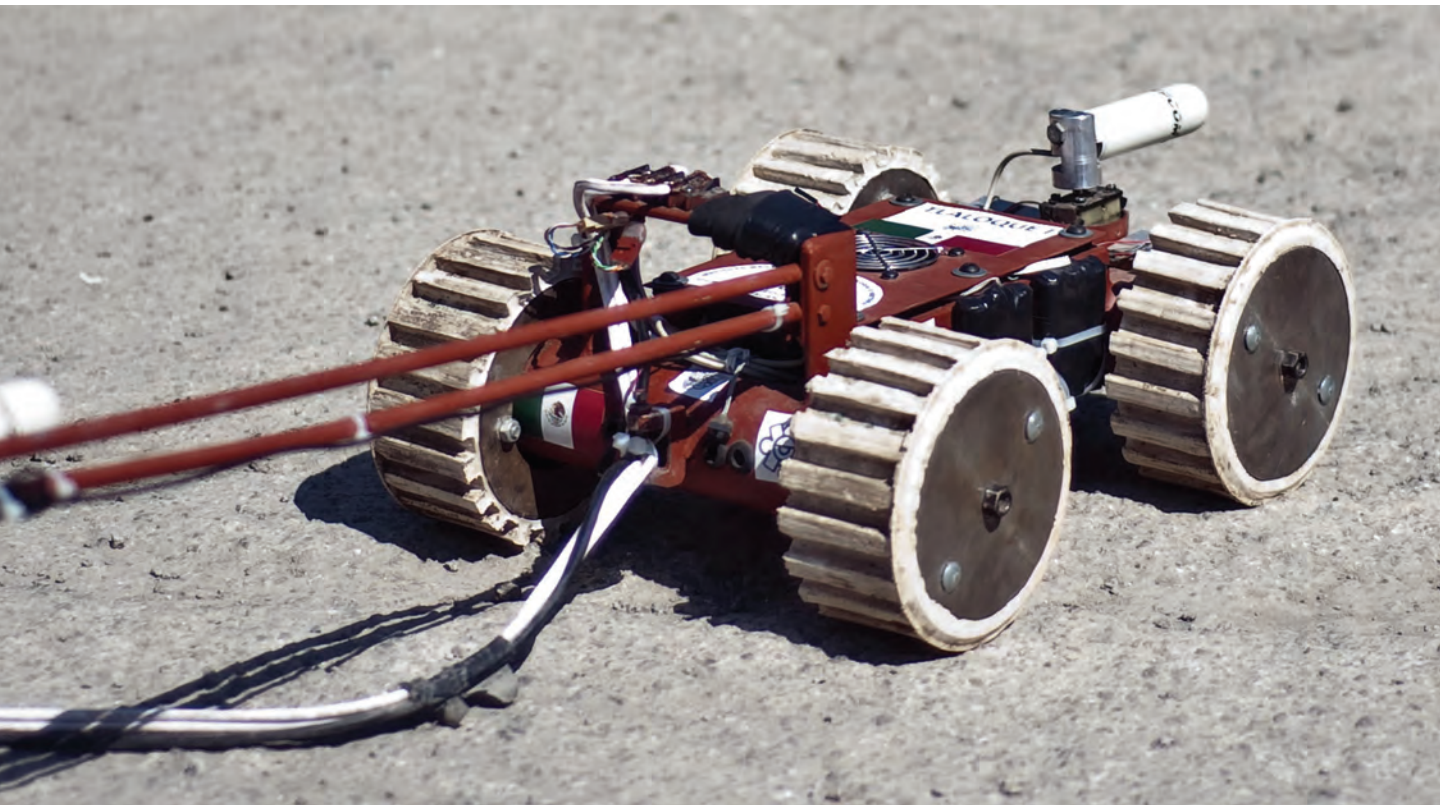
Finally, they assumed that the underground passage was visited frequently, but only by those individuals involved in rituals that bolstered their power. This was where such people acquired spiritual powers, by performing ritual acts. Some objects from the rituals, perhaps even the remains of those who gave and received gifts, might be present in the tunnel.

The underground excavations started in 2006 and continue to this day. Chávez began in an area of about 100 square meters, where he thought the main entrance to the tunnel once lay. A pit covering 5 square meters lay about 2 meters below the surface. This provided access to a tunnel leading toward the pyramid.

Artifacts and stone blocks filled the narrow passageway, making it hard to plan the excavation. Chavez turned once again to remote sensing, this time underground. This time he used a laser scanner—a highly accurate measuring device—to plan the next stage of the work. A first attempt recorded 37 meters of the tunnel. Another scan in 2011 reached 73 meters. These measurements confirmed that there was indeed a long tunnel leading toward the pyramid, but its precise overall length was still uncertain.

Next, Chávez used a small remote-controlled robot, equipped with video cameras. This penetrated 37 meters into the tunnel to test for stability and potential working conditions. This helped excavation of the previously laser-scanned segment of the passageway. In 2013, a more sophisticated robot with an infrared camera and a miniature laser scanner managed to get through the last, previously inaccessible 30 meters of the tunnel. This was no easy task. Ancient Aztec visitors had visited the tunnel on many occasions to leave offerings in the tunnel. To do so, they had to make their way through, and often partially demolish, more than 20 thick walls that had blocked it. In the end, the entire space was filled with offerings. Chávez and his

ARCHAEOLOGIST The robot "Tlaloque 1" was designed to investigate tunnels under Teotihuacán's pyramids.



Everything had a ritual significance—even the way the tunnel had been dug below the natural water table to re-create the watery environment of the underworld.

colleagues were the first people to enter the tunnel for 1,800 years.

By 2013, the excavation extended 65 meters into the tunnel. Two side chambers had come to light. Their walls and roofs had been finished using a powder created from a metallic mineral, and they shone like a starry night or like sparkling running water. One of the chambers contained more than 400 mineral metal balls. These objects remain a complete mystery. After the two side chambers, the tunnel's depth gradually increased by a further 2 meters and it continued for 35 meters to the east. At the end were three chambers, facing north, south, and east.

More than 75,000 objects have emerged from the excavation, which now extends over 103 meters of tunnel and to a depth of up to 17 meters below the surface. Thousands of offerings have come from the dig, among them minerals such as jade, serpentine, and turquoise; obsidian (volcanic glass); and liquid mercury. Hundreds of clay vessels and mirrors made from polished pyrite (a shiny mineral often confused with gold) lay alongside seashells. Dozens of unusual clay vessels have come to light, along with rubber balls, necklaces, wooden objects, and fragments of human skin.

What do all these finds mean? Chávez and his teammates argue that the Ciudadela re-created the sacred geography of the cosmos and the work of the gods. The Pyramid of the Feathered Serpent symbolized the Sacred Mountain, which served as a link between the various layers and regions of the cosmos. The underground tunnel and caves beneath the temple transformed space on earth into a wet, cold, dark underworld. It was there that rulers acquired the supernatural power to govern. The tunnel under the pyramid took the city's rulers into the underworld. Vanishing under the earth suggested that they could visit this unknown world, an act that gave them the ability to communicate with the forces of the supernatural realm. The Ciudadela was where everyone in the great city participated in public ceremonies that marked major events in the ritual calendar. It was there, too, that the architects attempted to create the entrance to the underworld.

The on-going Ciudadela project is no fast-moving search for precious objects, but rather a systematic, painstaking analysis of the meaning of the objects in the tunnel. Everything had a ritual significance—including the way the tunnel had been dug below the natural water table, in order to re-create the watery environment of the underworld. The last 30 meters of the tunnel had been made even deeper, so that they were always filled with water, representing the sacred water of the creation.

Investigations at Teotihuacán began a century ago, but the city is so enormous that they have hardly scratched the surface. The current emphasis is on tunneling—not only at the Ciudadela, but also under the Pyramids of the Sun and the Moon. Here further tunnels and rich offerings, as well as sacrificial victims, will help decipher the complex symbolism of one of the greatest cities in history.

Brian Fagan is a professor emeritus of anthropology at the University of California, Santa Barbara. He is the author of *Fish on Friday, The Little Ice Age, The Long Summer*, and the *New York Times* bestseller *The Great Warming.*

RONALDO SCHEMIDT / STRINGER / GETTY IMAGES

58

IN THINKING ABOUT THIS MONTH'S ISSUE, the question came up among staff: What interesting stories are out there that involve the self but do not involve people? We thought of many, everything from quantum particle self-energies to immune system foreign-body detection.

As varied as they were, these stories shared something in common: A fraught definition of the self. Calculations of self-energies have a bad habit of producing infinities. The possibility of auto-immune disease seems an inescapable tag-along to basic immune function.

Complex systems seem to resist the privileged perspective necessary to define a "self." If nature preaches a deep relativism, is our attachment to the idea of self a human foible?

Welcome to "Self."

—MS

"Cognitive scientists have long debated whether objects in our environment can become part of us."

KATIE REID
"Dear iPhone: It Was Just Physical, and Now It's Over" p.92

Self

NO OTHER

It's Time to Make Human-Chimp Hybrids

The humanzee is both scientifically possible and morally defensible

BY DAVID P. BARASH

IT IS A BIT OF A STRETCH, but by no means impossible or even unlikely that a hybrid or a chimera combining a human being and a chimpanzee could be produced in a laboratory. After all, human and chimp (or bonobo) share, by most estimates, roughly 99 percent of their nuclear DNA. Granted this 1 percent difference presumably involves some key alleles, the new gene-editing tool CRISPR offers the prospect (for some, the nightmare) of adding and deleting targeted genes as desired. As a result, it is not unreasonable to foresee the possibility—eventually, perhaps, the likelihood—of producing "humanzees" or "chimphumans." Such an individual would not be an exact equal-parts-of-each combination, but would be neither human nor chimp: rather, something in between.

If that prospect isn't shocking enough, here is an even more controversial suggestion: Doing so would be a terrific idea.

PIXABAY

THE YEAR 2018 IS THE BICENTENNIAL of Mary Shelley's *Frankenstein*, subtitled *the modern Prometheus*. Haven't we learned that Promethean hubris leads only to disaster, as did the efforts of the fictional Dr. Frankenstein? But there are also other disasters, currently ongoing, such as the grotesque abuse of nonhuman animals, facilitated by what might well be the most hurtful theologically-driven myth of all times: that human beings are discontinuous from the rest of the natural world, since we were specially created and endowed with souls, whereas "they"—all other creatures—were not.

Of course, all that we know of evolution (and by now, it's a lot) demands otherwise, since evolution's most fundamental take-home message is continuity. And it is in fact because of continuity—especially those shared genes—that humanzees or chimphumans could likely be produced. Moreover, I propose that the fundamental take-home message of such creation would be to drive a stake into the heart of that destructive

disinformation campaign of discontinuity, of human hegemony over all other living things. There is an immense pile of evidence already demonstrating continuity, including but not limited to physiology, genetics, anatomy, embryology, and paleontology, but it is almost impossible to imagine how the most die-hard advocate of humans having a discontinuously unique biological status could continue to maintain this position if confronted with a real, functioning, human-chimp combination.

It is also possible, however, that my suggestion is doubly fanciful, not only with respect to its biological feasibility, but also whether such a "creation" would have the impact that I propose—and hope. Thus, chimpanzees are widely known to be very similar to human beings: They make and use tools, engage in complex social behavior (including elaborate communication and long-lasting mother-offspring bonds), they laugh, grieve, and affirmatively reconcile after conflicts. They even look like us. Although such recognition has contributed to outrage about abusing chimps—as well as other primates in particular—in circus acts, laboratory experiments, and so forth, it has not generated notable resistance to hunting, imprisoning and eating other animal species, which, along with chimps themselves, are still considered by most people to be "other" and not aspects of "ourselves." (Chimps, moreover, are enthusiastically consumed in parts of equatorial Africa, where they are a prized component of "bush meat.")

In his book, *Less Than Human: Why We Demean, Enslave, and Exterminate Others*, David Livingstone Smith examined how dehumanization goes hand-in-hand with racism and genocide. Smith revealed a long-standing pattern whereby people, despite acknowledging that other human beings *appear* to be human, often maintain that in their essence—whatever that means—these others continue to be less than human. It is thus entirely possible that comparably stubborn biases will persist even if our biological continuity with other living things becomes undeniable. Moreover, people are certainly known to obscure inconvenient truths: It is said that when the wife of the Bishop of Worcester heard of Darwin's scandalous theory, she exclaimed "Descended from apes? My dear, let us hope that it isn't true, but if it is true, let us hope that it does not become widely known!"

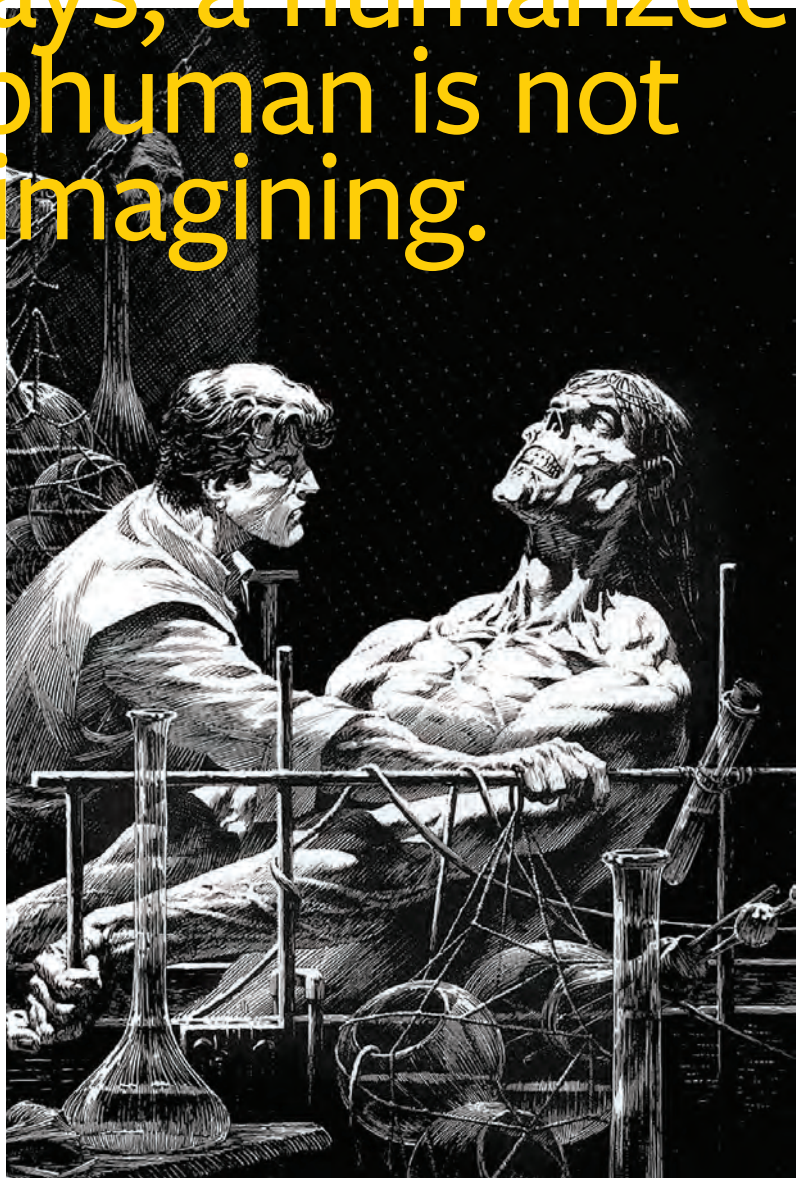
On the other hand, it seems equally likely that faced with individuals who are clearly intermediate between human and ape, it will become painfully obvious that a rigid distinction between the two is no longer tenable. But what about those presumably unfortunate individuals thereby produced? Neither fish nor fowl, wouldn't they find themselves intolerably unspecified and inchoate, doomed to a living hell of biological and social indeterminacy? This is possible, but it is at least arguable that the ultimate benefit of teaching human beings their true nature would be worth the sacrifice paid by a few unfortunates. It is also arguable, moreover, that such individuals might not be so unfortunate at all. For every chimphuman or humanzee frustrated by her inability to write a poem or program a computer, there could equally be one delighted by her ability to do so while swinging from a tree branch. And—more important—for any human being currently insistent upon his or her species' specialness, to the ultimate detriment of literally millions of other individuals of millions of other species, such a development could well be a real mind expander and paradigm buster.

IN THE EARLY DAYS OF BIOLOGY, when special creation ruled, it was widely thought that species were rigid and fixed, each specially created as such. Now we know better. As currently recognized, a species is a group of naturally interbreeding individuals; that is, a population within which genes are regularly exchanged. Moreover, even though people like to think in terms of yes/no, either/or dichotomies, we also know that the boundaries between species are shifting and flexible: e.g., perfectly "good" species such as mallards and pintail ducks often interbreed, producing hybrids that can be the bane of even experienced birders. Grizzlies and polar bears also hybridize on occasion, producing "grolar" bears.

A recent study of the genomes of ravens—which occupy much of the Northern Hemisphere—found that this species had earlier divided into two, with a smaller population limited to California. Then these two raven species recombined several hundred thousand years ago, forming the single Holarctic raven species that we know today.[1] Such "speciation reversal" may well be a more widespread phenomenon than previously thought. Elephants and mastodons

BOOK COVER OF *FRANKENSTEIN* / BERNIE WRIGHTSON

These days, a humanzee or chimphuman is not beyond imagining.

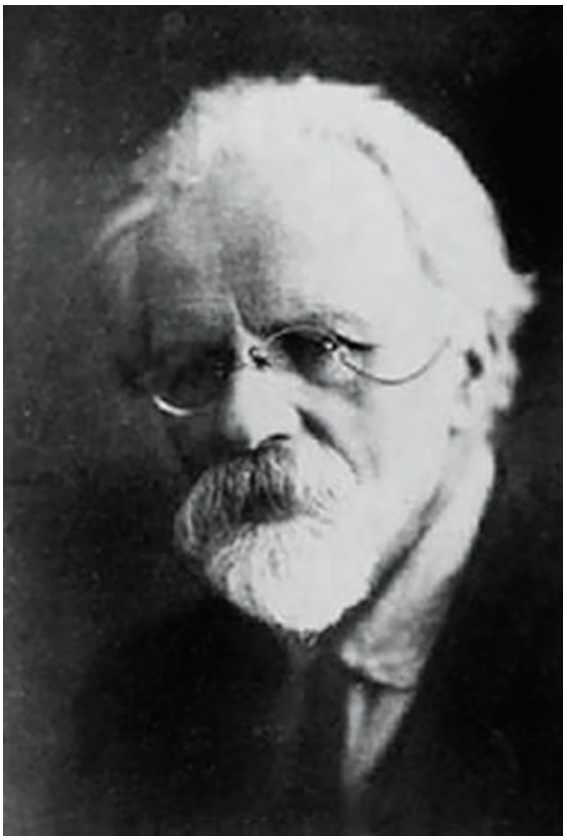


evidently interbred before the latter went extinct.[2] Wolves, coyotes, and domestic dogs have been hybridizing in recent decades, and it is clear that some populations of modern *Homo sapiens* contain as much as 5 percent Neanderthal genes, and some or all of us may also harbor an unknown soupcon from those mysterious hominins known as Denisovans. Princeton evolutionary biologist Rosemary Grant—who, along with her husband Peter, has long studied speciation among Galapagos finches—suggests that many animal species (including ourselves) are likely "haunted by the ghosts of interbreeding past."

The possibility thus cannot be excluded that combining human and chimp may herald, or threaten, something biologically new on our—and their—horizon.

A hybrid is a cross between individuals of distinct genetic ancestry, which means that technically, nearly everyone is a hybrid, except for clones, identical twins, or perhaps persons produced by close incest. More usefully, we speak of hybridization as the process by which members of different sub-species are crossed (mating Labradors and poodles, for example, to produce labradoodles), or—more rarely—different species, in which case the resulting hybrids are often nonviable, either sterile (e.g., mules, hybrids made by crossing horses and donkeys), or just plain unusual (e.g., tigrons, which have occasionally been generated by hybridizing tigers and lions, or ligers, produced vice versa). Hybrids are genetic mixtures, with essentially all body cells containing equal quantities of DNA from each parent. This, of course, is true of all sexually produced individuals, it's just that with hybrids, those two parents are likely to be more distantly related than is usual.

Chimeras, on the other hand, are somewhat different. They derive from what is essentially a process of grafting, whereby two genetic lines (most interestingly, different species) are combined to produce an individual that is partly of one genotype and partly of another, depending on which cells are sampled, and at what point in embryonic development. Probably because it is easier to imagine creatures produced by combining identifiable body parts from different animals than to picture a mingled, intermediate form, chimeras, more than hybrids, have long populated the human imagination. Ganesh, the Hindu god with a human body and



THE PIONEER Ilya Ivanovich Ivanov experimented with hybrids in the 1920s.

elephant's head, is a chimera, as are the horse-human centaurs of Western mythology. The classic "chimera" of Greek legend had the head and body of a lion, a tail that had morphed into the head of a snake and—to make a weird creature even more so—the head of a goat, sometimes facing forward and sometimes backward.

It is unclear whether my own imagined chimphuman will be a hybrid (produced by cross-fertilizing human and nonhuman gametes), or a chimera, created in a laboratory via techniques of genetic manipulation. I'm betting on the latter. Either way, human-chimp mixtures aren't a new idea.

During the 1920s, a Russian biologist with the marvelously Slavic name Ilya Ivanovich Ivanov appears to have made the first serious, scientifically informed efforts to create a genetic hybrid between chimpanzees and human beings. Ivanov had the perfect qualifications: Not only did he possess a special interest in creating interspecific hybrids, he was also an early specialist in artificial insemination, who had achieved international renown as a successful pioneer when it came to horse breeding. Prior to his work, even the most prized stallions and mares were limited to reproducing by "natural cover"—i.e., the old-fashioned way, one mounting at a time. But Ivanov found that by appropriate and careful dilution of stallion semen, combined with adroit use of the equine equivalent of a turkey baster, he could generate as many as 500 foals from a single genetically well-endowed stallion. His achievement caused a worldwide sensation, but nothing compared to what he next attempted.

And failed.

It happened initially at the Research Institute of Medical Primatology, the oldest primate research center in the world, located at Sukhumi, the capital of Abkhasia, currently a disputed region in the state of Georgia, along the Black Sea. At one time, the Sukhumi Institute was the largest facility conducting research on primates. Not coincidentally, Stalin is believed to have been interested in such efforts, with an eye toward developing the "new Soviet man" (or half-man, or half-woman).

Nor was Soviet interest in combining human and nonhuman genetic material limited to Russian biologists. The novelist Mikhail Bulgakov, best known—at least in the West—for his fantasy, *The Master and Margarita*, also wrote *Heart of a Dog*, a biting satire on early Soviet-era social climbers, in which a pituitary gland from a drunken person is implanted into a stray dog, who subsequently becomes more and more human—although not noticeably more humane as he proceeds to eliminate all "vagrant quadrupeds" (cats) from the city. Maxim Gorky was on board, writing approvingly that Lenin and his Bolshevik allies were "producing a most severe scientific experiment on the body of Russia," which would eventually achieve "the modification of human material."

Similar modification became a staple of Soviet biology, as well, as when S.A. Voronov attempted "rejuvenation therapy," a series of failed attempts to restore sexual function in rich, elderly men by transplanting slices of ape testes. But it was Ivanov who made the most serious efforts at combining human and nonhuman apes. Earlier in his career, in addition to the successful artificial insemination of horses, Ivanov had created a variety of animal hybrids, including "zeedonks" (zebras + donkeys) and different combinations of small rodents (mice, rats, and guinea pigs). For a time in the 1990s a fictional version of Ivanov was the chief character in a Russian-era television show portraying him as the "Red Frankenstein."

In 1910, Ivanov had announced, at a World Congress of Zoologists in Graz, Austria, that it might be possible to produce a human-ape hybrid via artificial insemination. During the mid-1920s, working at a laboratory in Conakry (then part of French Guinea) under the auspices of France's highly respected Pasteur Institute, Ivanov attempted just that, seeking without success to inseminate female chimpanzees with human sperm. (We don't know whose, and we also presume—although don't know for certain—that the attempted insemination was by artificial rather than natural means.) Then, in 1929, at the newly established Sukhumi Primate Research Institute, he endeavored to reverse donor and recipient, having obtained consent from five women volunteers to be inseminated—once again, presumably by artificial methods rather than "natural cover"—with sperm from chimpanzees and orangutans. Inconveniently, however, the nonhuman primate donors died before making their "donations," and for reasons that are unclear, Ivanov himself fell

WIKIPEDIA

out of political favor and was sent to Siberia in 1930; he died a few years later.

No one knows precisely what motivated Ilya Ivanov's early fertilization experiments. Maybe it was the allure of the possible, such that having discovered the potent hybrid-generating hammer of *in vitro* fertilization, everything—including eggs and sperm, with one from human and the counterpart from nonhuman primates—looked alluringly like a nail. Or maybe he was driven by the prospect of currying favor with Stalin, or of fame (or infamy) had he succeeded, or perhaps as an ardent atheist Bolshevik Ivanov was inspired by the prospect of disproving religious dogma.

In any event, Ivanov's story is not especially well known outside Russia, and insofar as Westerners learn of it, they are inclined to ridicule it as an absurd episode of reaching for a would-be "planet of the (communist) apes," or to inveigh against the immorality of such at attempt, which is increasingly feasible. To be sure, his crude efforts at cross-species hybridization are at present no closer to fruition, simply because even though human and chimp DNA are overwhelmingly similar, humans have 46 chromosomes whereas chimps have 48, so getting sperm from either species to combine with eggs from the other to produce viable offspring is—to put it literally—inconceivable.

These days, however, a humanzee or chimphuman is not beyond imagining. There have been many advances in biomedical research that not only emphasize the continuity between human beings and other animals, but that do so explicitly in the interest of human betterment. Research efforts are currently underway seeking to produce organs (kidneys, livers, etc.) that develop within an animal's body—pigs are the preferred target species—and whose genetic fingerprints are sufficiently close to the *Homo sapiens* counterpart to be accepted by a human recipient's immune system, while also able to function in lieu of the recipient's damaged organ. A human skin cell, for example, can be biochemically induced to become a "pluripotent stem cell," capable of differentiating into any human tissue type. If, say, a replacement liver is desired, these stem cells can be introduced into a pig embryo after first using CRISPR to inactivate the embryo's liver-producing genes. If all goes well, the resulting pig-human chimera will have the body of a pig, but containing an essentially human liver, which would then be available for transplantation into a person whose liver is failing.

After years of opposition, the U.S. National Institutes of Health announced in August, 2016 that it intends to lift its moratorium on stem cell research, which holds out promise for treating (perhaps even curing) many serious human diseases, such as cirrhosis, diabetes, and Parkinson's. Currently prohibited—and likely to remain so—is funding for studies that involve injecting human stem cells into embryonic primates, although inserting such cells into adults is permissible. Insofar as there is a biological line separating human beings from other species, it should be clear that this line is definitely permeable, not hard and fast, and is based more on ethical and political judgment than on science or technology. All sorts of things *can* be done; whether they *should*, is another question.

LOOKING FAVORABLY ON THE PROSPECT of a humanzee or chimphuman will likely be not only controversial, but to many people, downright immoral. But I propose that generating humanzees or chimphumans would be not only ethical, but profoundly so, even if there were no prospects of enhancing human welfare. How could even the most determinedly homo-centric, animal-denigrating religious fundamentalist maintain that God created us in his image and that we and we alone harbor a spark of the divine, distinct from all other life forms, once confronted with living beings that are indisputably intermediate between human and non-human?

In any event, the nonsensical insistence that human beings are uniquely created in God's image and endowed with a soul, whereas other living things are mere brutes has not only permitted but encouraged an attitude toward the natural world in general and other animals in particular that has been at best indifferent and more often, downright antagonistic, jingoistic, and in many cases, intolerably cruel. It is only because of this self-serving myth that some people have been able to justify keeping other animals in such hideous conditions as factory farms in which they are literally unable to turn around, not to mention prevented from experiencing anything approaching a fulfilling life. It is only because of this self-serving myth that some people accord the embryos of *Homo sapiens* a special place

as persons-in-waiting, magically endowed with a notable humanity that entitles them to special legal and moral consideration unavailable to our nonhuman kin. It is only because of this self-serving myth that many people have been able to deny the screamingly evident evolutionary connectedness between themselves and other life forms.

When claims are made about the "right to life," invariably the referent is *human* life, a rigid distinction only possible because of the presumption that human life is somehow uniquely distinct from other forms of life, even though everything we know of biology demonstrates that this is simply untrue. What better, clearer, and more unambiguous way to demonstrate this than by creating viable organisms that are neither human nor animal but certifiably intermediate?

DAVID P. BARASH is professor of psychology emeritus at the University of Washington. This article is somewhat modified from a chapter in his next book—*Through a Glass Brightly: Using Science to See Our Species as It Really Is*—which will be published summer, 2018, by Oxford University Press.

REFERENCES

1. Kelarns, A., *et al.* Genomic evidence of speciation reversal in ravens. *Nature Communications* **9** (2018). Retrieved from doi:10.1038/s41467-018-03294-w

2. Palkopoulou, E., *et al.* A comprehensive genomic history of extinct and living elephants. *Proceedings of the National Academy of Sciences* (2018). Retrieved from doi:10.1073/pnas.1720554115

Why Women Choose Differently at Work

Psychologist Susan Pinker on the role of choice in gender differences in the workplace

BY BRIAN GALLAGHER

IF YOU WERE TO PREDICT the future on the basis of school achievement alone, the world would be a matriarchy."

Susan Pinker, who wrote that sentence almost a decade ago in her book *The Sexual Paradox: Extreme Men, Gifted Women, and the Real Gender Gap*, could make the same claim today: A 2014 meta-analysis found that the "female advantage in school marks has remained stable in the data retrieved (from 1914 to 2011)."[1] Given that there's an overall female advantage in school—one largest in language courses, smallest in math courses, according to the paper—why isn't there a corresponding advantage, in terms of pay and high-powered positions, for females later, at work?

The developmental psychologist's answer hasn't changed since she wrote *The Sexual Paradox*: The female advantage at school doesn't translate to work partly because of the different career and lifestyle preferences men and women go on to develop, ones that aren't entirely culturally determined. These preferences, Pinker says, are a key part of the story about why women and men follow different career trajectories and schedules. Out-and-out discrimination, she argues, is still a problem and a significant part of the story—just not the whole story. For this, *The New York Times* called Pinker's book a "ringing salvo in the sex-difference wars" and Pinker, because of the psychological cast she gives to sex differences, a "difference" feminist. The *Telegraph*, meanwhile, found the book interesting ("much food for thought") but its case unconvincing ("more journalistic than scientific").

Nautilus recently caught up with Pinker so we could see for ourselves.

What does the most recent data on women's preferences regarding work tell us?

Studies show that, among other differences, educated women's career trajectories often have a different shape—based on their wider interests and a common desire to have flexible or part-time work when their

COMPASSIONATE EYE FOUNDATION / GETTY IMAGES

Women, on average, were more focused on investing in a society that was healthy and that provided for all.

families are young—and an accelerated pace later on. And women's careers tend to persist longer than men's do. After all, women live 5 to 8 years longer, and their careers tend to have more variety over their lifespans.

Do these differences persist among the gifted?
Results from a 2014 long-term study of gifted young adults show that women who have exactly the same level of ability as men often choose different life paths.[2] The study was conducted by David Lubinski, Camilla P. Benbow, and Harrison J. Kell from Vanderbilt University. They followed up on teenagers who tested at the top 1 percent in mathematical reasoning ability (they also followed another cohort that had high levels of verbal abilities) four decades later to find out what were they doing. Many of the women and men had different career outcomes, but they also had different preferences and values, which had a big role to play in their career choices. For example, most of the men were more concerned with outward, personal success and felt that society should invest in them because their ideas were better than other people's. Whereas the women, on average, were more concerned with fairness: that members of society should not go without what they needed, and that they had a role to play

in ensuring that fairness. The men, on average, were more focused on their own achievements and on creating concrete things. Women, on average, were more focused on investing in a society that was healthy and that provided for all. There were more men in STEM careers than there were women. But there were more women in medicine, law, health, and education.

Are these differences the result of biological or cultural differences?

I think that both play a role. It's simplistic and scientifically untrue to say it's one or the other. The two sexes are not blank slates, even if a gender-continuum exists. The weight of the evidence shows that most women and men are pretty similar on average, and that the differences are more evident at the extremes. And many technology positions may well attract male extremes. It may be a certain type of guy who is drawn to IT jobs, a particularly systematic and single-minded male. In my recent book, *The Village Effect: How Face-to-face Contact Can Make Us Healthier and Happier*, I present evidence that some of the choices that women make, such as devoting a lot of time grooming their close relationships, help to extend their lifespans. It's essentially a question of where we shift our telescope. If we focus our telescope on what men have traditionally valued, which is high-income and STEM jobs and long work-hours, say over 60 or 70 hours a week, then yes, women are not there, at 50/50, and I don't think they will ever be—even if we had the most gender-neutral society possible. But if we aim our lens on lifespan, career satisfaction, and close personal relationships nurtured over decades—relationships that have been shown to protect cognition, resilience, and immunity—then men, on average, trail well behind women. If men want to live longer, happier lives, they have a lot of catching up to do. It all depends on the outcomes you value most.

Do women and men regard part-time careers differently?

In the Netherlands, for example, where part-time work is legally protected for both men and women—you can't lose your job if you're full-time and then want to work three days a week—they found the vast majority of people who choose to work part-time are women. Indeed, 62 percent of the women who work part-time don't even have children at home. They work part-time because they have other priorities in their lives—their relationships, their friends, their outside interests. When we look at the North American data, we find that people who choose flexible jobs or schedules in industries that offer those options, two-thirds of them are women. Most, but not all of them are mothers.

Doesn't this put them at a disadvantage?

Many women put their eggs in a number of baskets—their families, their friends, their interests—as opposed to putting them in just one: their careers. In fact, this more diverse set of interests and skills protected women after the financial crisis of 2008. Fewer women than men were unemployed, and fewer women committed suicide due to financial losses and a complete loss of

identity. When you ask women to describe their ideal job, most women—especially highly educated women—say they want to work with people they respect; they want to do a job that's meaningful, that provides social contact, and that is flexible. Most tech jobs do not satisfy those criteria.

How does government support for part-time and flexible career choices affect outcomes?

In the United States, a woman can't even take off six months with a new baby without losing face, or losing her job. It's not like this everywhere. A senior newspaper editor who interviewed me in the Netherlands when I was on a book tour for *The Sexual Paradox* had a very high-level job, and she worked part-time, which surprised me. I said, "Why do you work part time?" She answered, "Well, Wednesday afternoons is for my aging parents and for my friends. And Friday is for piano. I'm a very serious piano player, and I want to reserve time in my life for something that gives me joy." Protected part-time work might be one of the reasons why Dutch women are happier than American women: They have more career options than we do.

Would gender disparity in career outcomes decrease or increase as a society becomes more egalitarian?

I can't predict the future, but several excellent recent studies show that, paradoxically, as a society becomes more egalitarian, the gender gap in occupational choice becomes wider, not narrower. A case in point: A study published last month in *Psychological Science*, by the psychologists David Geary and Gijsbert Stoet, looked at the academic performance of nearly half a million adolescents from 67 countries.[3] What they found was that the more gender equal a country was, as determined by the World Economic Forum's Global Gender Gap Report, the fewer women ultimately took up STEM paths in college. Countries with the most robust legal and cultural protections for gender equality—along with the strongest social safety nets—such as Sweden, Switzerland, Norway, and Finland, have the fewest female STEM graduates, weighing in at about 20 percent of the total (the U.S. has 24 percent). In contrast, countries with almost no protections, with few guarantees for women and where life satisfaction is low—such as Algeria, Tunisia, the United Arab Emirates, Turkey, and Albania—had by far the highest representation of women in STEM, approaching the researchers' estimates of 41 percent, based on how well girls do in math and science in high school, without considering their other skills. Another study showing this paradoxical effect, from 2008, was led by David Schmitt.[4] He and his colleagues found that gender differences in personality are *way larger* in cultures that offer more egalitarian gender roles and opportunities. This is not what one would predict if men's and women's preferences were exclusively constrained by cultural forces.

What do you think accounts for this paradox?

The researchers in the *Psychological Science* study also examined the range of strengths and weaknesses *within* each student. Girls were capable of college level STEM studies nearly everywhere they looked, but they had even higher scores in reading—reading was more likely to be their personal strength—whereas boys' strengths (relative to themselves) were more likely to be in science. If the boys chose a career based on their personal strengths, it would most often be STEM, whereas girls, especially those in countries where they felt free to make their own choices, could choose either, but often followed the lead of *their* own strengths and interests.

Do other psychologists agree with this interpretation?

I checked this interpretation out with Wendy Williams, Cornell psychologist and co-author, with Stephen Ceci, of the seminal book, *Why Aren't More Women in Science?* She concurred. "If the environment offers options for a good life in multiple domains of work, then girls choose to pursue what they are best at relative to their other abilities. This might be STEM, or it might be law, for example. However, if the environment offers limited options and if the best options are in STEM careers, girls tend to focus more on their skills in STEM. The key is that girls and women are making choices that maximize their success, and these choices are not always for careers in STEM." In places where girls and women feel they have the freedom to make their own choices, in other words, they are more likely to act on their personal strengths and interests. But in places where they feel constrained by cultural or financial

strictures, they are more likely to go for what they consider a sure thing, which is a STEM career. I absolutely agree with and promote equal access to opportunities and education. But equal access to opportunities and education does not determine an equal result. Assuming that women are simply a tamped down, smothered version of men—and would always choose what men choose if they only had the chance—is neither respectful of women's autonomy nor supported by the data.

BRIAN GALLAGHER is the blog editor at *Nautilus*.

REFERENCES

1. Voyer, D. & Voyer, S.D. Gender differences in scholastic achievement: A meta-analysis. *Psychological Bulletin* **140**, 1174-1204 (2014).

2. Lubinsky, D., Benbow, C.P., & Kell, H.J. Life paths and accomplishments of mathematically precocious males and females four decades later. *Psychological Science* **25**, 2217-2232 (2014).

3. Stoet, G. & Geary, D.C. The gender-equality paradox in science, technology, engineering, and mathematics education. *Psychological Science* (2018). Retrieved from DOI:10.1177/0956797617741719

4. Schmitt, D.P., Realo, A., Voracek, M., & Allik, J. Why can't a man be more like a woman? Sex difference in big five personality traits across 55 cultures. *Journal of Personality and Social Psychology* **94**, 168-182 (2008).

Dear iPhone: It Was Just Physical, and Now It's Over

The cognitive science of my breakup with my smartphone

BY KATIE REID

AS A KID, I'D SOMETIMES TRY to imagine what life would be like without a particular sense or part of my body, like with questions from the *Would You Rather?* game. *Would you rather be deaf or blind? Would you rather have no legs or no arms?* I'd try to erase the sound of my mom's piano playing, the sight of the ground growing smaller as I soared on the tree swing in my backyard, or the feeling of playing basketball so hard my lungs might explode, but I just couldn't. How could life go on without these sensations that were so tied to my idea of what it meant to be alive?

I guess I've been feeling extra contemplative and nostalgic these days because I recently went through a pretty significant break-up ... with my smartphone. My relationship with my phone was unhealthy in a lot of ways. I don't remember exactly when I started needing to hold it during dinner or having to check Twitter before I got out of bed in the morning, but at some point I'd decided I couldn't be without it. I'd started to notice just how often I was on my phone—and how unpleasant much of that time had become—when my daughter came along, and, just like that, time became infinitely more precious. So, I said goodbye. Now, as I reflect on the almost seven years my smartphone and I spent together, I'm starting to realize: What I had with my phone was largely physical.

Cognitive scientists have long debated whether objects in our environment can become part of us. Philosophers Andy Clark and David Chalmers argued in their 1998 paper "The Extended Mind" that when tools help us with cognitive tasks, they become part of us—augmenting and extending our minds.[1] Today the idea that phones specifically are extensions of ourselves is receiving a lot of attention. In February, in *Aeon*, philosopher Karina Vold explored the legal implications of applying the extended mind theory to our smartphones.[2] If the extended mind view is correct, she writes, then smartphones would merit recognition "as a part of the essential toolkit of the mind." In April, in a fascinating *New Yorker* profile of Clark, Larissa MacFarquhar wrote that Clark thinks "we are all cyborgs, in the most natural way. Without the stimulus of the world, an infant could not learn to

COLLAGE ART BY FRANCESCO IZZO


iPhone

Without my phone, I'm more fully myself.

hear or see, and a brain develops and rewires itself in response to its environment throughout its life. Any human who uses language to think with has already incorporated an external device into his most intimate self, and the connections only proliferate from there."[3] For Clark, MacFarquhar continues, "The more devices and objects there are available to foster better ways of thinking, the happier he is."

I agree with the theory, if not Clark's sunny outlook on its implications. (More on that later.) However, when it comes to the most widely useful of modern-day tools—the smartphone—both of these recent articles overlook a key component of the extended self: embodiment. Our devices aren't just extensions of our minds, they're extensions of our bodies, too.

Clark ventures into embodiment in his 2008 book, *Supersizing the Mind*, in which he spends half of the first chapter discussing how bodies and senses adapt to external technology. From a monkey learning to master a robotic arm to the familiar process of "body babbling," in which infants learn, through practice, how neural commands control certain bodily movements, Clark shows that the ability to incorporate new objects into our bodies is part of how we're designed:

> Because bodily growth and change continue, it is simply good design not to permanently lock in knowledge of any particular configuration but instead to deploy plastic neural resources and an ongoing regime of monitoring and recalibration.

I experienced that recalibration when I got my first smartphone in 2011. In those first few weeks, it had a particular kind of novelty about it—merely owning it was obvious and unnatural. That solid, black iPhone 4 felt a bit unwieldy in my palm at the beginning, and pulling it out to Google something at dinner with my friends or to take a picture of something on the street was noticeable. Soon after, though, it went from being a bulky accessory to a predictable character trait, gradually and quietly gaining entry to a more intimate part of myself—a part fueled largely by instinct. When I was waiting in line at the grocery store or sitting alone at the bus stop, I reached for my phone without even thinking. That soothing scroll through Instagram or Twitter became much like a 21st-century finger-tapping or knee-jiggling.

It had become, in Clark's words, "transparent equipment." And the physiological effects of losing that equipment were acute: my heart began to race in the Verizon store when the employee told me he was deactivating my phone, and in the following hours and days, I would frequently find myself reaching for my iPhone, the way a girl reaches for a non-existent

ponytail after a drastic haircut. Of course, I would gradually begin to notice not being able to use Google Maps or post to Instagram, but the physical sense of loss was instantaneous and intense. I literally felt a part of me was missing.

My smartphone obviously helped me with a great number of cognitive tasks. It communicated with my friends. It managed my finances. It delivered work emails. It alerted me to emergencies in the area. It reminded me of appointments. It captured and stored memories. But this sudden and overwhelming awareness of its physical absence indicated that it had become just as important to my body as it had to my mind. If I'm honest, much of what I did on my phone could be characterized as mindless. I can't count the number of times I pulled out my phone just for the feeling of unlocking the screen and swiping through applications, whether out of comfort—like a baby sucking her thumb—or boredom—like a teenager at school, tapping his fingers on a desk. In those cases, I sought not mental stimulation, but physical release.

While Clark celebrates the idea of innovative devices ushering in new possibilities for the mind, I find myself wondering what we might be giving up along the way. If personal technology is improving the world of thought, what is it doing to the world of our moving, breathing bodies? Clark may see a smartphone extending my mind, but I could feel it dulling my senses.

Without my phone, I'm more fully myself, both in mind and body. And now, more than ever, I know that looking at my phone is nothing compared to looking at my daughter while the room sways as I rock her to sleep, or how shades of indigo and orange pour in through the window and cast a dusky glow over her room, or the way her warm, milky breath escapes in tiny exhalations from her lips, or how the crickets outside sing their breathless, spring lullaby. See, once I looked up from my phone, I remembered that each experience could be a symphony for the senses, just like it had been when I was a child and, thank God, there was no such thing as smartphones.

KATIE REID is the director of digital media at The Boys' Latin School of Maryland and an MFA candidate in integrated design at the University of Baltimore.

REFERENCES

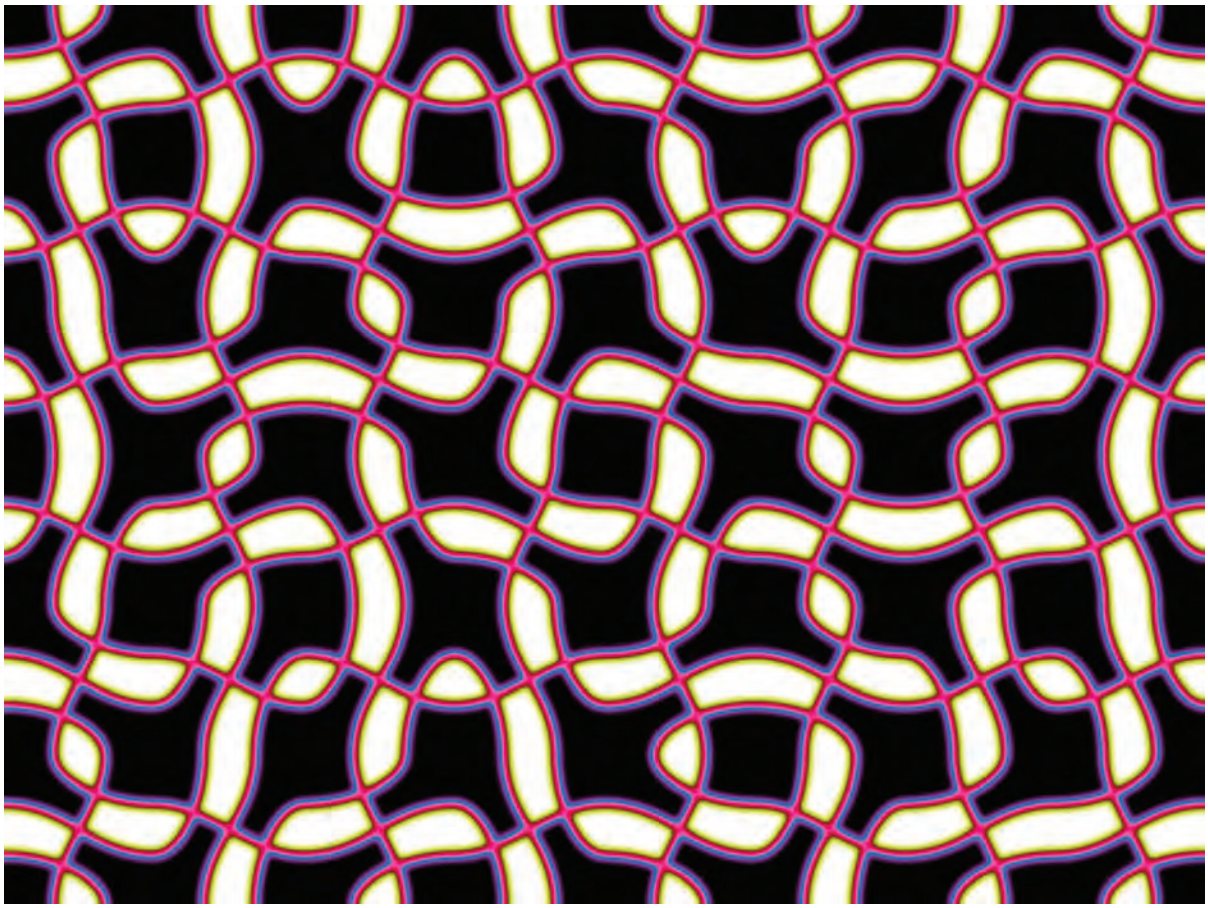
1. Clark, A. & Chalmers, D. The extended mind. *Analysis* **58**, 7-19 (1998).

2. Vold, K. Are 'You' Just Inside Your Skin or Is Your Smartphone Part of You? *Aeon* aeon.co/ideas (2018).

3. MacFarquhar, L. The Mind-Expanding Ideas of Andy Clark *The New Yorker* (April 2, 2018).


CARNEGIE LECTURES ON DEMAND
Exceptional science streams here
Travel to the stars. Splice genes.
Share the "aha" moment.
Watch videos of exceptional science anytime, anyplace.
For free.
Visit our growing video library.
carnegiescience.edu/CSEvideos
CARNEGIE SCIENCE
COSMOLOGY • ASTRONOMY • PLANETARY EVOLUTION
HIGH-PRESSURE PHYSICS • MATERIALS SCIENCE • GEOPHYSICS
GEOCHEMISTRY • MOLECULAR BIOLOGY • DEVELOPMENTAL BIOLOGY
PLANT SCIENCE • EVOLUTION • GENETICS • ECOLOGY
@carnegiescience
facebook.com/carnegiescience
These videos are made possible by the generous support of Margaret & Will Hearst.

CULTURAL PROGRAMS OF THE NATIONAL ACADEMY OF SCIENCES



Gymnasts, 1996, Giclée print

Process, Chance, and Serendipity:

Art That Makes Itself

An Exhibition by **Paul Brown**

February 20 – July 15, 2018

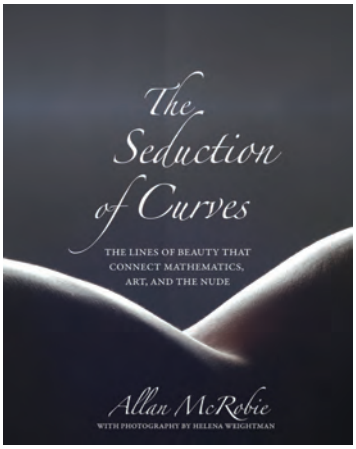
2101 Constitution Ave., N.W., Washington, D.C.
West Gallery. Open weekdays 9-5. Free.
Photo ID required.

#ArtMakesItself

@CPNAS

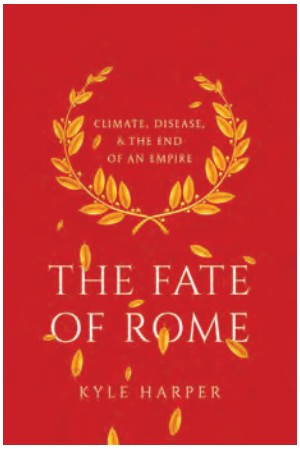
FOR MORE INFORMATION, VISIT WWW.CPNAS.ORG.


PLANET EARTH
Blue Planet II
BBC
AMERICA
SATURDAYS 9/8C

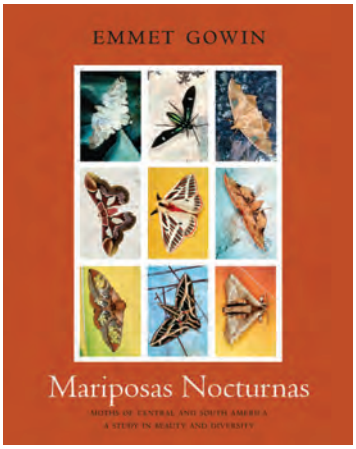


"This is what a book should be: startling, bold, and beautiful, idiosyncratic and yet universal."
—Steven Strogatz, author of *The Joy of x*

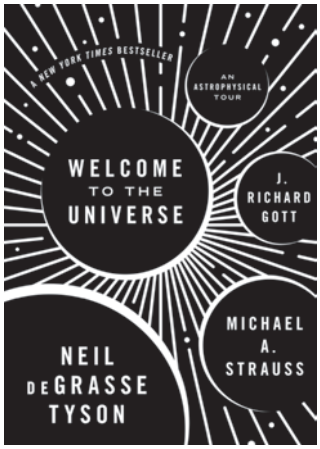
The full-color companion book to the spectacular five-part PBS series



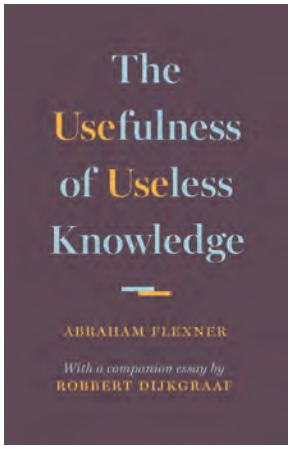
"A breakthrough in the study of the Roman world—intrepid, innovative, even revolutionary."
—Walter Scheidel, author of *The Great Leveler*



"Moths fly by night and Gowin's project is, at its heart, about drawing his jewels out of the shadows. In this sense, *Mariposas Nocturnas* returns full circle to the invention of photography itself."
—Andrea K. Scott, *New Yorker*



"A bracing expedition through dusty galactic hinterlands and the vast theoretical vistas of Albert Einstein's work."
—*Nature*



"These two eloquent essays are timely and timeless treasures that remind us why and how the pursuit of knowledge for its own sake has transformed humanity and human affairs."
—Sean B. Carroll, author The *Serengeti Rules* and *Brave Genius*

SANTA FE
INSTITUTE
www.santafe.edu

The Santa Fe Institute is the world headquarters for complexity science, operated as an independent, nonprofit research and education center located in Santa Fe, New Mexico.

aging

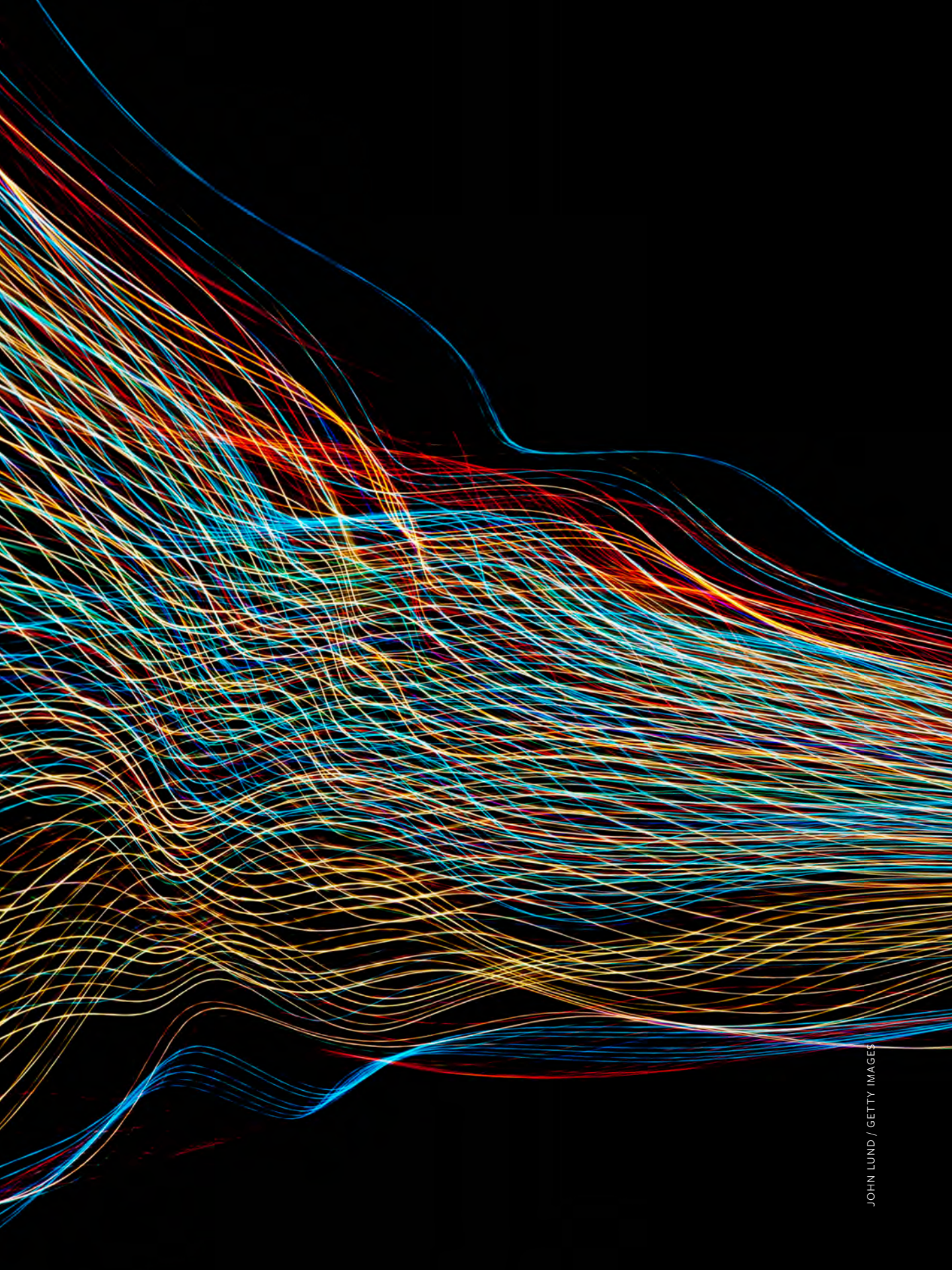
is the climate change of human biology

GLENN FOUNDATION
FOR MEDICAL RESEARCH

SCIENCE
PHILANTHROPY ALLIANCE

Advancing basic science—The foundation of our future

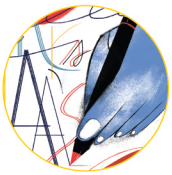
www.sciphil.org



JOHN LUND / GETTY IMAGE$

Issue Index

24



23

NOV/DEC 2017

22

SEPT/OCT 2017

21

JULY/AUG 2017

20

MAY/JUNE 2017

19

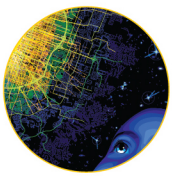
MAR/APR 2017

18

JAN/FEB 2017

17

NOV/DEC 2016



16

SEP/OCT 2016

15

JULY/AUG 2016

14

MAY/JUNE 2016

13

MAR/APR 2016

12

JAN/FEB 2016

11

NOV/DEC 2015

10

SEP/OCT 2015

09

JULY/AUG 2015

08

MAY/JUNE 2015

07

MAR/APR 2015

06

WINTER 2015

05

FALL 2014

04

SUMMER 2014

03

SPRING 2014

02

WINTER 2014

01

FALL 2013

SUBSCRIPTIONS
Address subscription and address changes to:
Nautilus
25 Broadway, 9th Floor
New York, NY 10004;
phone: 212-221-3870;
email: order@nautil.us
Visit subscribe.nautil.us for more information.

POSTMASTER
Send address changes to:
Nautilus
25 Broadway, 9th Floor
New York, NY 10004

Richard Powers

The National Book Award-winning novelist, whose latest, The Overstory, *explores the ecology of trees, reflects on the themes in* Nautilus

INTERVIEW BY KEVIN BERGER

PERSPECTIVE

Which is a more amazing story: that some omnipotent force (who by coincidence looks just like us) whipped up everything *ex nihilo*, created us like Geppetto created Pinocchio, then set us loose to ponder his magnificence, or that a few simple forces, through countless trillions of steps in an unsponsored process produced people capable of understanding the nature and function of genes? The second story feels many orders of magnitude more mysterious and overwhelming than any supernatural explanation. I love that scientific culture, which half a century ago felt compelled to suppress all appeal to artistic awe, now realizes the need to encourage narrative wonder as a driver of empirical discovery. And I love to see art placing those empirical discoveries at the heart of the human story, where they belong.

SELF

Grasping the underlying material principles of life has profoundly changed our self-conception. That concept has changed for so long, in such gradual steps, that we can't see how differently we think about ourselves, compared to the basic assumptions about humanity throughout most of history. In my novels, I'm pushing back against this notion that a mechanistic view reduces our humanity. It doesn't. There's a beautiful Lewis Thomas essay, "On Matters of Doubt," in which he says the common denominator between science and art is bewilderment. People who have found consilience between those two forms of bewilderment see that the self has grown so wildly complex it now wants to grasp the chemical and physical nature of its own origin.

ILLUSTRATION BY FRANCESCO IZZO

COMMUNITIES

The scientist Suzanne Simard has found Douglas firs that are rhizomatically connected to birches. If you cut down the nurturing fir, the nurtured birch suffers. Trees taking care of other trees! That's a revolution in the way we need to think about evolution. For every act of competition—nature red in tooth and claw—there are many acts of cooperation—nature floating on a sea of green. Here's the key: "Survival of the fittest" means organisms most fit for their environment. But the environment consists almost entirely of other *living things*. Millennia before science verified trees communicated with each other, people thought they did. Something primal in us already apprehends that these creatures have agency. In the earliest myths, trees and people were kin. Sadly, we inherited one of the few old traditions that doesn't have deep respect for plants. In *The Overstory*, Patricia Westerford gives a lecture mentioning how Noah brought all the animals two by two onto the ark but left the plants to die. She says, "He failed to take the one thing needed to rebuild life on land, and concentrated on saving the freeloaders!"