

NAUTILUS

ANTHROPOLOGISTS IN LOVE

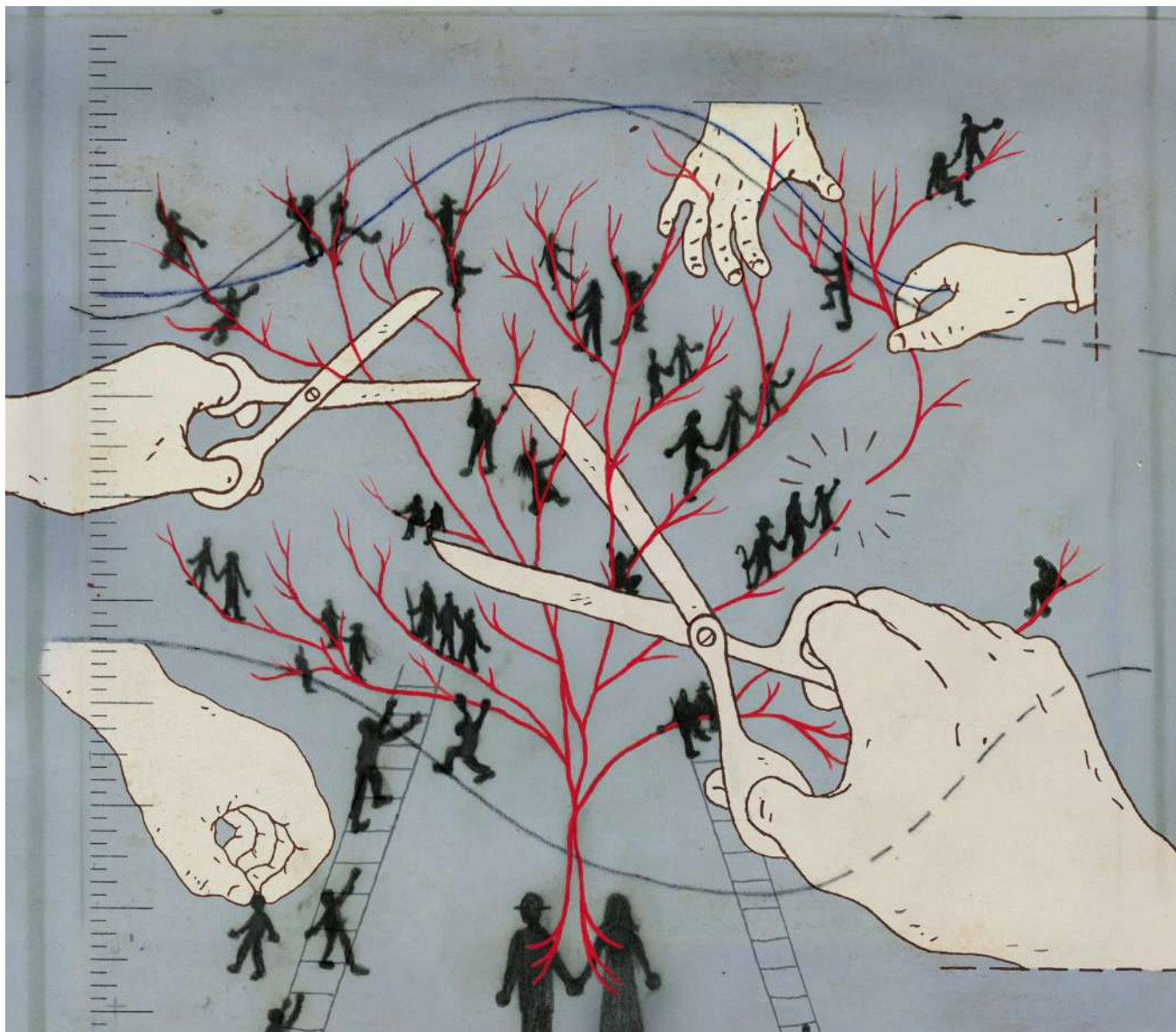
Margaret Mead's eternal flame

THE UNIVERSE IS DONE MAKING STARS

When the lights go down in the cosmos

NATURAL ISN'T ALWAYS BETTER

Evolution can be a cruel mistress



How Eugenics Shaped Statistics

EXPOSING THE DAMNED LIES OF THREE SCIENCE PIONEERS P.20



TO RESEARCH
BETTER
PROTECT

marine.science brings together scientists from across the globe to conduct collaborative, interdisciplinary research in one the world's largest marine protected areas. This incredible ocean observatory is helping scientists understand complex marine ecosystems – so they help protect the ocean for future generations.

www.marine.science



Contents

Editor's Note

- 5 *The Statistics Story*
BY KEVIN BERGER

Reader Response

- 7 *Comments and letters about stories from print issue 32*

Preludes

- 12 *A theory physics doesn't need; what orcas can teach us about gender; the trouble with behavioral science; the future of sex; and a few of the solar system's secrets*

Cover Story

SCIENCE PRACTICE

- 20 *Damned Lies*
Eugenics and the myth of objectivity in statistics
BY AUBREY CLAYTON

The Last Word

- 108 Joe Pettit
The engineer on what it takes to live and work in Antarctica
INTERVIEW BY MARISSA GRUNES

COVER Jonathon Rosen



Stay curious⁵



5 is a non-profit media foundation telling strong and inspiring stories,
spotlighting new perspectives and courageous profiles.
Let's change the scene. Join us here: fivemedia.com

Features

ASTRONOMY

- 38 The Universe Has Made Almost All the Stars It Will Ever Make

Black holes are cosmic dimmers

BY CALEB SCHARF

ANIMALS

- 42 Eels Don't Have Sex Until the Last Year of Their Life

Why eels are one strange fish

BY STEVE PAULSON

PSYCHOLOGY

- 48 Are You Yoda or Darth Vader?

How to recognize your light and dark sides

BY BRIAN GALLAGHER

ANTHROPOLOGY

- 56 Gender Is What You Make of It

Margaret Mead, Ruth Benedict, and the relationship that changed social science

BY CHARLES KING

ARCHAEOLOGY

- 66 An Ancient Site with Human Skulls on Display

Where our ancestors began to elevate themselves above nature

BY JO MARCHANT

NEUROSCIENCE

- 72 The Hard Problem of Breakfast

How does it emerge from bacon and eggs?

BY JONATHAN BINES

EVOLUTION

- 76 Just Because It's Natural Doesn't Mean It's Good

We are well advised to not lose track of evolution's dark side

BY DAVID P. BARASH

CHEMISTRY

- 82 Show Me How to Say No to This

How drugs today can cure a crushing love

BY BRIAN D. EARP & JULIAN SAVULESCU

EVOLUTION

- 90 The Price of Life Is Death, but Sex Improves the Exchange Rate

Calculating the evolutionary success of Homo sapiens

BY AARON HIRSH



NAUTILUS

EDITORIAL

NautilusNext CEO
Nicholas White

Publisher & Editorial Director
John Steele

Editor
Kevin Berger

Managing Editor
Liz Greene

Associate Editor
Brian Gallagher

Copy Editor
Teresa Cirolia

Design
Tasnuva Elahi

BOARD OF ADVISORS

David Agus *Professor of Medicine and Engineering, University of Southern California*

Bob Bazell *Adjunct Professor of Molecular, Cellular, and Developmental Biology, Yale University*

Christina Beck *Head of Science & Corporate Communications, The Max Planck Society*

Sean Carroll *Senior Research Associate, Department of Physics, California Institute of Technology*

Jennifer Dunne *Professor and V.P. for Science, Santa Fe Institute*

Josh Empson *Managing Director, Providence Equity Partners*

Bran Ferren *Co-Chairman, Applied Minds, Inc.*

Stuart Firestein *Chairman of the Department of Biological Sciences, Columbia University*

Jessica Flack *Professor and Director, Collective Computation Group, Santa Fe Institute*

Peter Galison *Pellegrino University Professor in History of Science and Physics, Harvard University*

Thomas Campbell Jackson *Venture Partner, Easton Capital Investment Group*

Beth Jacobs *Managing Partner, Excellencia Global Partners*

David Kaiser *Germeshausen Professor of the History of Science, MIT*

Lisa Kaltenegger *Associate Professor of Astronomy, Cornell University and Director of the Carl Sagan Institute*

Sep Kamvar *LG Associate Professor of Media Arts and Sciences, MIT; Director of the Social Computing Group, MIT Media Lab*

David Krakauer *President, Santa Fe Institute*

Ben Lamm *Founder and CEO of HyperGiant*

Barnaby Marsh *Senior Advisor to the President, John Templeton Foundation*

Gayil Nalls *Artist, Philosopher, and Writer*

Elisa New *Powell M. Cabot Professor of American Literature, Harvard University*

Gerry Ohrstrom *Private Investor and Producer; Former Chairman of G.L. Ohrstrom & Co. and the Ohrstrom Foundation*

Jerry Sabloff *External Professor and Past President, Santa Fe Institute*

Paula Sabloff *External Professor, Santa Fe Institute*

Caleb Scharf *Director of Astrobiology, Columbia University*

Ian Tattersall *Curator Emeritus, American Museum of Natural History*

Geoffrey West *Distinguished Professor and Past President, Santa Fe Institute*

Published by:



NAUTILUS *Next*

Copyright © 2020. All rights reserved.

The Statistics Story

BY KEVIN BERGER

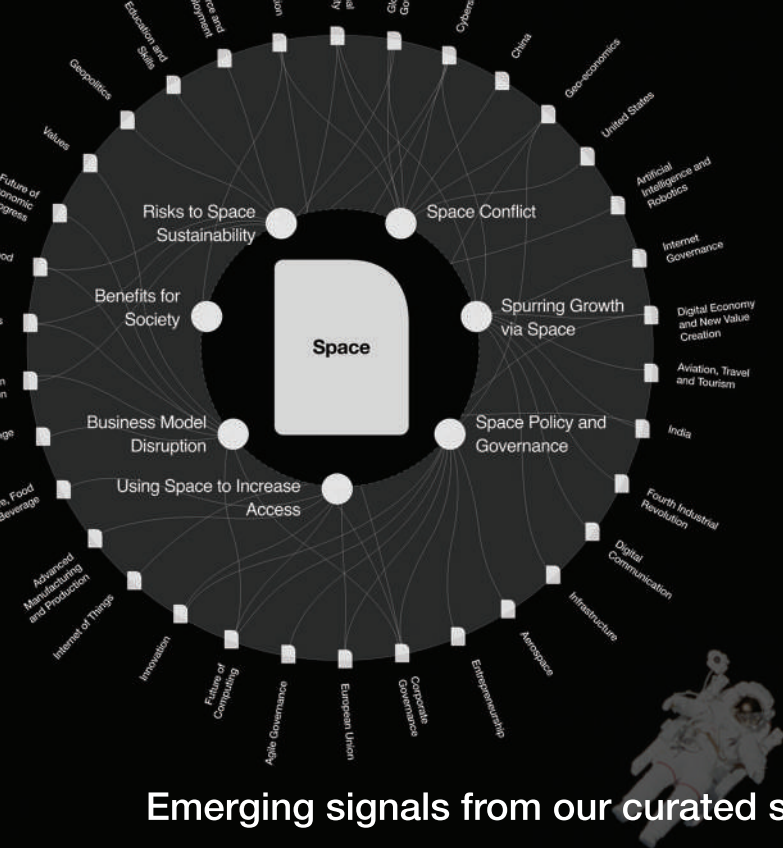
IT'S AN AGELESS ARGUMENT in art and literature: Can you separate the art from the artist? Do awful personal characteristics of an artist—anti-Semitism, racism, misogyny—taint how you experience their works? I think they do, because a work can't fully take flight in my mind when I know the artist is a wretch. I love reading biographies and histories of artistic periods, which spell out the screwy upbringings and cultures that shaped artists and their works. But that context, while fascinating, still clips the wings of an artwork's transcendence for me. I've grown lousy at compartmentalizing.

You might think science, especially a branch of science as cold as statistics, would be immune to the prejudices of scientists themselves. Scientific methods are designed to rule out human subjectivity, crowning results with a kingly objectivity. But this issue's cover story, "Damned Lies: Eugenics and the Myth of Objectivity in Statistics," shows otherwise. Author and mathematician Aubrey Clayton treats us to a narrative that flows like a movie about the lives and scientific methods of statistics pioneers Francis Galton, Karl Pearson, and Ronald Fisher; brilliant men, for sure, and a veritable triumvirate of silk-stocking racists.

"I was trying to write a story about problems with statistical thinking in the 21st century," Clayton says, explaining what spurred his journey back in time. "There's a real case to be made that people have been doing statistics in a logically incorrect way for the last 100 years. We're seeing that with the replication crisis, in which experiments can't be duplicated." Clayton learned the pioneering trio developed statistical methods in concert with their personal views that populations should be weeded of socially undesirable people, including "the Negro race," Galton wrote, and those who were physically or mentally disabled. "They took absolutely no pains to separate their views from their statistical works," Clayton says.

Clayton's article, shocking as it is in places, showing the trio's influence on Hitler, penetrates the heart of scientific practice and its social consequences. "My sincere hope in telling this story is that it offers a rich appreciation for where statistical ideas come from," Clayton says. "It's one of the most damaging myths of statistics that somehow it was inevitable and a singular truth that should be applicable to everyone. Putting it in a historical context makes you understand those things are not inevitable."

In the early 20th century, Clayton says, the revered statistical authority behind eugenics wrote the people, the scientists, out of the story. "But if we start to realize that statistics is always about human stories and human endeavors, then we won't fall prey to that kind of authority-seeking anymore." When the discipline of statistics moves past the white colonial mindset of its British founders, Clayton says, and includes many different kinds of perspectives, "We will see a richer and less colonial statistics that's going to be better for everyone."



COMMITTED TO
IMPROVING THE STATE
OF THE WORLD

The World is changing

Get ready for the future with our Digital Membership

Emerging signals from our curated sources



“Scientists seek to eliminate all forms of bias from their research. However, all scientists also make assumptions of a non-empirical nature about topics such as causality, determinism and reductionism when conducting research. Here, we argue that since these ‘philosophical biases’ cannot be avoided, they need to be debated critically by scientists and philosophers of science.”

PubMed



“Data from a 2012 study of more than 4,000 published papers show that scientific literature as a whole is trending towards more positivity. The study’s author, Daniele Fanelli, found that the frequency at which papers testing a hypothesis returned a positive conclusion increased by more than 22% from 1990 to 2007. By 2007, more than 85% of published studies claimed to have produced positive results. Fanelli concluded that scientific objectivity in published papers is declining.”

Nature

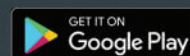


“Even among more reliable disciplines, problems can arise when scientific findings are overstated in courtrooms and handled without independent review or input from the scientific community,” said moderator Katy Naples-Mitchell, a Houston Institute legal fellow, whose opening remarks focused on a landmark 2009 National Academy of Sciences report that found that many wrongful convictions derived from forensic evidence that was flat-out wrong, calling for widespread reform.”

ProPublica



digital-members.weforum.org



Readers Respond

Comments and letters about stories from print issue 32.

“COULD AN AI BE IMMORTAL?”

While we’re at it, any idea where your personality comes from? It’s controlled in the prefrontal cortex of your brain, but no one has found where in the body it is. Personality is different from consciousness, because virtually any living thing can be considered conscious (go to food, avoid danger, etc.) but only some have personalities. Maybe String Theory has another view that also suggests a kind of eternal life for those living things, including you!

—Howard Jeffrey Bender

“THE IDEA OF ENTROPY HAS LED US ASTRAY”

The idea that we have to live differently in the future is so obvious that I cannot comprehend those who assure us that all our solutions are just technological. We need technology, but above all, we need to change our minds. Technology is easy, to change our primate behavior seems much more difficult.

—jmdsceg

The author seems to ignore the human society before the industrial revolution. People then were living according to his idea, in agrarian, eco societies. But they were poor, ill, and suffering an incredibly tragic existence; famines were rampant; diseases killed in huge numbers; children died very young. Despite the world “brimming with energy.”

What changed that is precisely the industrial revolution and science, which brought immense relief worldwide; intensive agriculture probably saved billions.

—Filotas

“DON’T FEAR THE ROBOT”

Thanks. There is still a lot of room for devices doing specialized tasks, but our romantic notions of general purpose robots that duplicate what humans do are flat-out wrong. That was the same message at the Long Now Boston conversation with Bruce Blumberg on the future of robots. He speculated that the bigger breakthroughs will come from collaborations between devices and humans—a cyborg rather than a robotic future.

—George Gantz

“MICE ON ACID”

Another disgusting, unneeded, and completely useless experiment on animals.

—J-chuck

So much thorough research and insights condensed in such a short piece! I love learning something new and chuckling in the process—keep ’em coming

—Bob Hope



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

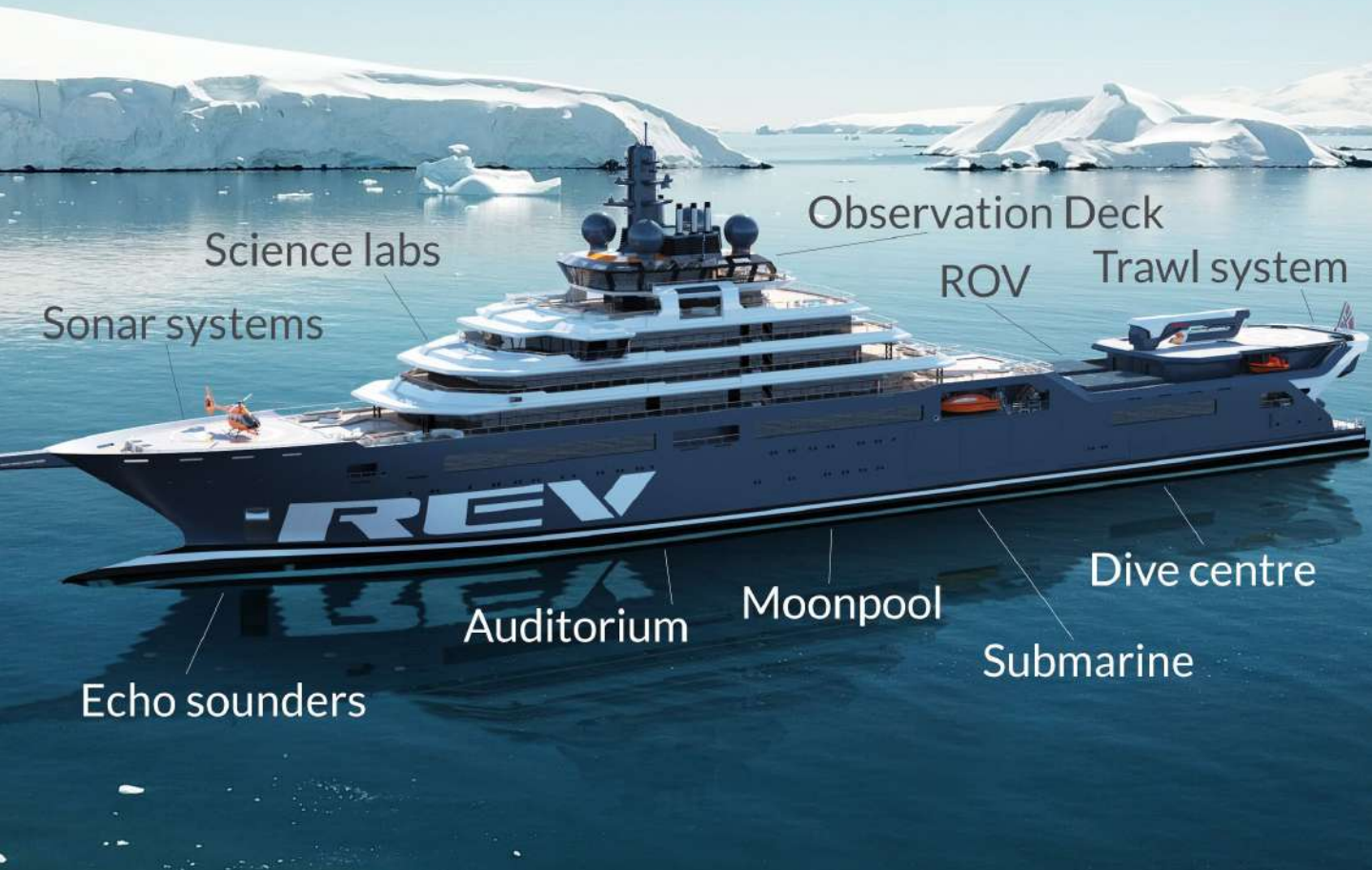
CONTACT

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

subscriptions
Visit subscribe.nautil.us

REV Ocean

From curiosity to understanding to solutions



www.revocean.org
One Healthy Ocean

Define *essential*.

[KNOWLEDGE DEFIES ENTROPY.]



SF PRESS

THE SANTA FE INSTITUTE PRESS | www.sfpres.org

SFI Press is an initiative of the Santa Fe Institute.

Pictured volume: *InterPlanetary Transmissions: Stardust*. To get your free ebook,* visit SFIPress.org/Nautilus

*Offer good through the end of the world or 12/31/20, whichever comes first.



Based at Campus Biotech in Geneva, **Mackenzie Mathis** holds the Bertarelli Chair in **Integrative Neurosciences** at the École polytechnique fédérale de Lausanne. Her research into adaptive motor control is seeking to answer one of neuroscience's most fundamental questions: how does the brain adapt the signals it sends to muscles to make our body move?

I D E A S S P A R K E D
K N O W L E D G E S H A R E D
R E S E A R C H A D V A N C E D
T H E R A P I E S D E V E L O P E D



#BertarelliNeuro

Founded in 2010, the **Bertarelli Foundation's neuroscience research programme** has, as its guiding principle, a commitment to funding research that breaks down barriers across geographies, institutions and disciplines. By fostering new collaborations, the **#BertarelliNeuro** programme is helping to bridge the gap between basic and translational neuroscience, and its teams are addressing medical issues that, once solved, will have life-changing outcomes for patients.

fb fondation
bertarelli

www.fondation-bertarelli.org

**We need
racial justice
to achieve
climate justice**



$$\begin{array}{l}
 \vec{E} = \sum_{i=1}^n \vec{E}_i \quad \rho = mg \quad C = \frac{\epsilon_0 \epsilon_s \mathcal{E}}{d} \quad T_0 = 2\pi \sqrt{\frac{m}{k}} \quad \gamma = \ln \frac{A(t)}{A(t-T)} \quad v_k = \frac{A}{h} \\
 v = \frac{1}{f} \quad R = \sigma T^4 \quad T = \frac{2\pi}{\omega} \quad \chi = \beta T \quad \Psi_n = \sqrt{\frac{2}{l}} \sin \frac{n\pi x}{l} \quad \omega = \sqrt{\omega_0^2 - \beta^2} \\
 x = A \cos(\omega t + \alpha) \quad \omega = 2\pi\nu \quad \Phi = BS \cos \alpha \quad E = mc^2 \quad h\nu = A + \frac{mv^2}{2} \quad \Delta m > 0 \quad \Delta m < 0 \quad C = c \cdot \mu \\
 \sigma = 5.67 \cdot 10^{-8} \frac{W}{m^2 \cdot K^4} \quad W = |\Psi|^2 \quad p = \frac{mv}{\sqrt{1 - \frac{v^2}{c^2}}} \quad m_0 = - \quad \langle \lambda \rangle = (\sqrt{2\pi} d n)^{-1} \\
 R = \alpha \sigma T^4 \quad \alpha = f_0 \epsilon^{\beta_1} \cos(\omega t + \alpha) \\
 \lambda_m = \frac{b}{T} \quad b = 2.9 \cdot 10^{-3} m \cdot K \quad \beta = \frac{r}{2m} \quad \Delta N = N \frac{4}{\sqrt{\pi}} \bar{e}^{\pm i} \Delta u \\
 \varphi = \arctg \frac{A_1 \sin \alpha_1 + A_2 \sin \alpha_2}{A_1 \cos \alpha_1 + A_2 \cos \alpha_2} \quad \lambda = \lambda \quad k = \frac{2\pi}{\lambda} \\
 \Delta z = m \lambda_s, m = 0, 1, 2, \dots \quad R_p = \frac{f_0}{2\pi \sqrt{\omega_0^2 - \beta^2}} \quad W = \frac{1}{2} m \beta^2 \omega^2 \quad E = A \cos(\omega t - kx) \quad \lambda \\
 A_p = \frac{f_0}{2\pi \sqrt{\omega_0^2 - \beta^2}} \quad W = \frac{1}{2} m \beta^2 \omega^2 \quad E = A \cos(\omega t - kx) \quad \lambda \\
 M = F \cdot b \quad \Delta \varphi = \frac{2\pi}{\lambda} \Delta x \quad \rho = \vec{p}_1 + \vec{p}_2 + \dots + \vec{p}_n \\
 \eta = \frac{1}{3} p \langle v \rangle \langle \lambda \rangle \quad U = \frac{1}{2} \frac{q}{r} RT \quad \frac{\partial V}{\partial T} = \frac{q}{r} \cdot \frac{m}{M} = 8.31 \quad v = \frac{h}{m \lambda} \cdot \frac{q}{r} \quad \sigma = e n (u_n + u_p) \\
 A = I \Delta \Phi \quad \sigma_z = \frac{1}{2} \hbar \omega (n=2) \quad \phi(x) \quad p_x = \frac{3\hbar}{2} \frac{r}{l} \\
 \end{array}$$

Do We Need a Theory of Everything?

Now, three of the fundamental interactions, the electromagnetic and the strong and weak nuclear force,

We need a theory of quantum gravity because general relativity and the standard model are mathematically

incompatible. So far, this is a purely theoretical problem because with the experiments that we can currently do, we do not need to use quantum gravity. However, this will hopefully change in the coming decades.

Besides the missing theory of quantum gravity, there are various other issues that physicists have with the standard model. Most notably it's that, while the three forces in the standard model are all of the same type, they are also all different in that each of them belongs to a different type of symmetry. Physicists would much rather have all these forces unified to one, which means that they would all come from the same mathematical structure.

In many cases that structure is one big symmetry group. Since we do not observe this, the idea is that the big symmetry would manifest itself only at energies so high that we have not yet been able to test them. At the energies that we have tested it so far, the symmetry would have to be broken, which gives rise to the standard model. This unification of the forces of the standard model is called a "grand unified theory."

What physicists mean by a theory of everything is a theory from which all the four fundamental interactions derive. This means it is both a grand unified theory and a theory of quantum gravity.

This sounds like a nice idea, yes. But. There is no reason that nature should actually be described by a theory of everything. While we *do* need a theory of quantum gravity to avoid logical inconsistency in the laws of nature, the forces in the standard model do not have to be unified, and they do not have to be unified with gravity. It would be pretty, yes, but it's unnecessary. The standard model works just fine without unification.

So this whole idea of a theory of everything is based on an unscientific premise. Some people would like the laws of nature to be pretty in a very specific way. They want it to be simple, they want it to be symmetric, they want it to be natural. So they have an idea of what they want to be true. Then they stumble over some piece of mathematics that strikes them as particularly pretty and they become convinced that certainly it must play a role for the laws of nature. In brief, they invent a theory for what they think the universe *should* be like.

This is simply not a good strategy to develop scientific theories, and no, it is most certainly not standard

Nature doesn't give a damn what physicists think is pretty math.

methodology. Indeed, the opposite is the case. Relying on beauty in theory development has historically worked badly. In physics, breakthroughs in theory-development have come instead from the resolution of mathematical inconsistencies.

The search for a theory of everything and for grand unification began in the 1980s. To the extent that the theories which physicists have come up with were falsifiable they have been falsified. Nature clearly doesn't give a damn what physicists think is pretty math.

I don't like commenting on individual people's theories of everything. I don't like it because it strikes me as deeply unfair. These are mostly researchers working alone or in small groups. They are very dedicated to their pursuit and they work incredibly hard on it. They're mostly not paid by tax money so it's really their private thing and who am I to judge them?

The problem is when theories that have turned out to be useless grow to large, tax-paid research programs, as has happened with string theory and supersymmetry and grand unification. That creates a problem because it eats up resources and can entirely stall progress, which is what has happened in the foundations of physics.

The brief summary is that if you hear something about a newly proposed theory of everything, do not ask whether the math is right. Because many of the people who work on this are really smart and they know their math and it's probably right. The question you should ask is what reason do we have to think that this particular piece of math has anything to do with reality. "Because it's pretty" is not a scientific answer. And I have never seen a theory of everything that gave a satisfactory scientific answer to this question.

—Sabine Hossenfelder

ANIMALS

No, Animals Do Not Have Genders

ANIMALS DO NOT have genders. Although this statement is universally accepted by those who study and theorize about gender, there is a lot of confusion about it among those who do not.

The confusion stems from the fact that males and females of many species systematically behave in different ways. Perhaps the most basic example is the act of mating. But in some parts of the animal kingdom, sexually differentiated behavior goes beyond the act of mating. Sometimes only one sex will care for the young. Other species have sex-specific mating and courtship strategies, like harem defense by male gorillas, or mating dances. In still others, males and females have different patterns for sociality, as in big-horned sheep, which have sex-segregated herds.

How are these behaviors different from gender? To answer this question we need an understanding of what gender is, and this can be a bit tricky. The term gender has been used in many ways, and for many purposes. Gender is complex and multi-faceted, and it makes perfect sense for people to address different aspects of it in different ways.

It wasn't until the 1950s that psychologist John Money started using the term "gender role" to refer to something that associates with biological sex, but is not the same. From there, a theoretical distinction emerged where sex refers to facts about biological bodies. Gender, on the other hand, is cultural. It involves a set of behaviors and norms that shape how men and women act, prescribe how they ought to be, and specify what it means to be a man or a woman. These behaviors and norms emerge as a result of cultural evolution, and are transmitted to new generations through cultural learning. (Notice here that I implicitly refer to a two-gender system. I am not making a political point. This is just the most common type of system across cultures, traditionally.)



As gender theorists have pointed out, sex and gender cannot be fully pulled apart. Facts about our sexed bodies influence the cultural rules surrounding gender. (For instance, in many cultures it is a norm that men, who are typically males, do jobs that require a lot of upper body strength.) And facts about gender in turn shape our sexed bodies. (For instance, norms of what is attractive lead to different patterns of exercise, like weightlifting for men and running on the elliptical for women.) But despite this intertwining, peacocks still do not have genders. And the reason is that peacocks do not have culture.

How do we know that gender is not simply a biological fact? What makes it cultural, rather than analogous to sex-differentiated behavior in animals? Unlike in any other animal, gendered behavior in humans is wildly different across cultures. What is considered appropriate for women in one culture might be deemed completely inappropriate in another. Even the number of genders is culturally variable. While most cultures have settled on two genders, associated with biological sex differences, others settle on three or more.

Relatedly, the rules and patterns of gender change over time. While in the early 1900s women in the United States were forbidden from wearing trousers, it is now perfectly acceptable to do so. And while pink is

Peacocks still do not have genders. And the reason is that peacocks do not have culture.

now considered the color of femininity in the Western world, this association only emerged recently. In other words, there is a lot of arbitrariness to gender—it is flexible, it can be done in many ways. And this indicates that it is deeply shaped by culture.

But wait—don't animals have cultures? And, if so, couldn't they have genders, too? Culture relies on the transmission of learning and information from generation to generation. This allows stable patterns of useful behavior to emerge and persist. And it allows us

to build up cultural knowledge over these generations. Some animals can engage in this sort of learning, at least in a limited way. Killer whales, for example, learn how to hunt from each other, and different groups develop different strategies for killing prey.

But genuine examples of animal culture are relatively rare, and do not involve sex-specific patterns of behavior and learning the way human gender does. We do not, for instance, see killer whale pods where females learn special behaviors only from females, and pass these on only to other females. Even if we did, this sort of proto-gender would be missing many of the key features of human gender systems. Most importantly, human gender systems involve healthy doses of normativity—not only do women behave a certain way by dint of their cultural training, but we agree as a society that they *should* behave that way. This element is absent from animal cultures.

—Cailin O'Connor

PSYCHOLOGY

How the Pandemic Has Tested Behavioral Science

IN MARCH 2020 the United Kingdom curiously declined to impose significant social distancing measures in response to the global pandemic.

The government was taking advice from several parties, among them the so-called “Nudge Unit,” a private company called Behavioral Insights Team that uses behavioral science to advise policy makers how to “nudge” people toward certain actions. Chris Whitty, England’s Chief Medical Officer, reportedly cited “behavioral fatigue,” the idea that the public’s commitment to the measures would fade over time, as a policy concern. This shaped the country’s pandemic response. The lax measures sparked fierce backlash not just from epidemiologists, but also from a group of 600 behavioral scientists. They signed an open letter doubting the quality of the evidence that led to the government’s decision.

There is some evidence for behavioral fatigue, but probably not enough for it to form the foundation of a country’s response to a deadly pandemic. The U.K.



Psychology has a long and well-publicized struggle with quality control.

eventually bowed to the pressure and ramped up its efforts to slow the virus' spread by banning mass gatherings, requiring 14 days of self-isolation for anyone with COVID-19 symptoms, and encouraging people to avoid non-essential travel and contact with others. But the debate about how and when behavioral science should shape public policy rages on.

The lack of a vaccine means our best countermeasure against the pandemic is to change our behavior. To that end, a group of behavioral scientists led by Jay Van Bavel and Robb Willer published a paper on how social and behavioral science could support the response to the pandemic. It highlights research on topics like science communication, moral decision-making, and stress and coping. The goal of the paper, they wrote, is to "help align human behavior with the recommendations of epidemiologists and public health experts." The authors suggest that it may be helpful for public health officials to spread messages that give people a sense of connection to their local community or their fellow citizens.

If insights like these make people a little more likely to take the recommended precautions, it could mean the difference between life and death. So why *shouldn't* we listen to behavioral scientists?

Behavioral science—and psychology in particular—has had a long and well-publicized struggle with quality control. Many influential experiments have failed to hold up after further scrutiny, often due to small and non-representative samples, sloppy data analysis, and highly context-specific findings. This has exposed systemic flaws in how behavioral science is conducted and interpreted—making it shaky ground for any public policy. "As someone who has been doing research for nearly 20 years," wrote social psychologist Michael Inzlicht, "I now can't help but wonder if the topics I chose to study are in fact real and robust. Have I been chasing puffs of smoke for all these years?"

Psychology and other fields are making progress in addressing their flaws, but it remains true that in the interplay between behavioral science and policy, puffs of smoke abound. Deciding whether to base policy on behavioral science comes down to a tricky balance between the pros and cons of acting on imperfect evidence.

In a preprint responding to Van Bavel and Willer's paper, psychologist Hans IJzerman and his colleagues proposed a system they call "evidence readiness levels," which they describe as "guidelines for flagging trustworthy and actionable research findings." Based on a similar system that NASA uses to assess its technology, evidence readiness levels range from preliminary observations, at level 1, to field-tested solutions that are ready to deploy in a crisis, at level 9. But is that appropriate during a pandemic, when public health officials are compelled to try to change people's behavior, with or without input from behavioral science?

Other evidence-evaluation frameworks have been proposed, but no matter which approach behavioral scientists take, it will have to involve an answer to the same difficult question: What level of uncertainty is acceptable? Until behavioral scientists come to an agreement about how big the gray areas can be, public health officials, educators, and all others who seek insights from behavioral science may just have to decide for themselves.

—Scott Koenig

SOCIOLOGY

Sexless in the City

THE PANDEMIC IS MAKING its way into every corner of our lives—even the bedroom. Despite initial reports that lockdowns were giving folks some much needed time for sexual self-care, a recent analysis by the Kinsey Institute showed that "widespread social restrictions put in place during the COVID-19 pandemic appear to have significantly disrupted sexual routines and the overall quality of people's sex lives." Roughly 43 percent of the study's 1,550 respondents said that



they had experienced a significant decrease in sexual frequency during lockdown relative to the previous year.

Interestingly, a small group of respondents, some 13 percent, reported an improvement in their post-lockdown sex lives. To determine who these people were, Justin Lehmiller, lead author of the original study in the journal *Leisure Sciences*, conducted a secondary analysis of the data. From the background questions included with the survey that established things like demographics, perceived risk from the pandemic, and political orientation, he determined that self-identified conservatives accounted for the bulk of the satisfied population.

The data imply that the post-pandemic cityscape may be less sexy than the countryside.

Lehmiller isn't that shocked by the results. Reached by phone, he suggested that since "we know there are differences in social distancing and perceived threat of the virus, it makes intuitive sense that conservatives are having more sex than their liberal counterparts." A more relaxed perspective on the severity of the pandemic may prevent the increased cortisol levels that have been shown to inhibit sexual desire.

One interesting subtext of the data suggests it's city dwellers who are experiencing the brunt of the sexual downturn. A cursory glance at geographic distribution of party affiliation in the U.S. clearly shows that today's conservatives are found everywhere except city centers. While there are exceptions to the liberal-urban/conservative-rural divide, for instance Vermont or Staten Island, the trend persists. Alongside their U.S. counterparts, predominantly rural-dwelling British conservatives also report increased sexual satisfaction.

Together, the data imply that the post-pandemic cityscape may be less sexy than the countryside. Like

Lehmiller suggested, cityside liberals may be taking contact restrictions more seriously than their rural, conservative counterparts. The downside of this? It may be that self-isolating urbanites are running up against biochemical limitations of their responsible choices.

Solo play just isn't as satisfying as partnered activities, and could be driving urban decreases in sexual activity. A study from Scotland's University of Paisley found that partnered sex releases 400 percent more prolactin, the neurohormone responsible for feelings of sexual satiety, than does masturbation. This may explain the Kinsey finding that "generally, only partnered activities were linked to improvements."

But while some city dwellers are dreaming of exchanging a fifth-floor walkup for a suburban townhouse, plenty of others are turning to what they know best—technology. Although solo activities haven't been as satisfying in the past, the willingness of urban dwellers to adopt new technologies may not keep things that way for much longer because sextech, a \$30 billion industry of toys, apps, robots, and virtual reality is poised for its moment in the sunroom.

Bryony Cole, a consultant for the industry and host of the Future of Sex podcast, emphasizes that she's seen an uptick in creative approaches to making the most of lockdowns. Online group chats are "replacing the bar or a party as a pick-up zone, and the emergence of online sex parties and mixers is allowing people to dip their toes into worlds they may have been hesitant to explore in the physical realm." The normalization of new kinds of online interactions may still allow the sex lives of city slickers to rebound.

Whether virtual interactions are able to recapitulate the neurohormonal benefits of partnered sex remains to be determined. As with the rest of the topsy-turvy conditions brought on by the pandemic, it seems that the future of American sexuality is volatile and hard to predict. One thing that seems certain is something different is coming soon.

—Anastasia Bendebury & Michael Shilo DeLay



ASTRONOMY

The Dark Side of the Solar System

BY COREY S. POWELL

ALTHOUGH LIGHT MIGHT SEEM to be the dominant element in the sky, darkness often contains the most powerful lessons. Darkness defined the most awesome and most feared of astrological events, a total eclipse of the sun, and inspired some of the greatest advances in the history of science. In modern times, solar eclipses led to the discovery of the element helium and violent eruptions on the sun; in 1919, the shadow of a solar eclipse enabled researchers for the first time to validate Albert Einstein's general theory of relativity. All across the solar system, darkness exposes the secret locations that light only obscures: the remarkable places where moons are ripped apart, comets are born, and alien life may be swimming about in an ice-cloaked ocean.

The most gorgeous eclipses in the solar system are never visible from Earth.

ECLIPSED BY A RINGED PLANET

The most gorgeous eclipses in the solar system are never visible from Earth, but one of them was captured by the Cassini spacecraft. On Oct. 17, 2012, during its 174th orbit of Saturn, it passed directly behind the planet and plunged into its shadow. Light from the eclipsed sun can be seen streaming around the edges of Saturn, which allows researchers to study the structure of the planet's thick, windy, hydrogen-helium atmosphere.

The greatest visual drama comes from the planet's rings. Nothing you see here is illuminated directly by the sun; rather, sunshine is scattering off the icy chunks that comprise the rings. The colors indicate the structure and composition of those chunks, while the brightness indicates their average size; evidently, they range in scale from dust specks to floating icebergs the size of a small house. The unusual palette is partially due to this unfamiliar type of illumination, and partly due to the way the image was composed: Cassini's imaging camera took three pictures in infrared, red, and violet light, which were then combined to simulate a color view.



NASA / JPL-CALTECH / SPACE SCIENCE INSTITUTE

GEYSERS IN THE TWILIGHT

Enceladus is another fascinating body whose secrets emerge only if you don't look at it too directly. The warm ocean hidden beneath its ice might well have remained hidden and unknown, if not for a crucial clue that literally leaked out: Geysers of water erupt from fissures in the south pole of this 310-mile-wide moon. The geysers are subtle features, invisible in direct images of the surface of Enceladus. But they pop out when seen in silhouette against empty space, especially if backlit by the sun.



In this Cassini image, taken on Nov. 30, 2010, multiple geysers are spouting off in a variety of directions. The shadow of Enceladus against the geysers helped scientists determine the location and geometry of the geysers; watching how those shadows changed over the course of a season further refined the information. Chemical analysis of the material that is shooting out showed that, along with the expected water and salts, the geysers contain organic compounds. Cassini's instruments also detected the presence of silica, which can get mixed with water in undersea volcanoes.

Taken together, the evidence indicates Enceladus has both the raw ingredients for life and a potential energy source. Hydrothermal vents on Earth support rich ecosystems. But if there is life on Enceladus, it may be hard to find. Even in its thinnest spots, the icy crust is probably at least a mile thick.

VENUS' INNER HEAT

The second planet from the sun gets no respect; the United States hasn't sent a spacecraft to Venus in more than 30 years. The planet is covered with perpetual, unbroken clouds that reflect 75 percent of the light that hits them. That makes Venus bright and beautiful in Earth's skies, but difficult to study in any meaningful way—at least, as long as you are limiting yourself to visible light.

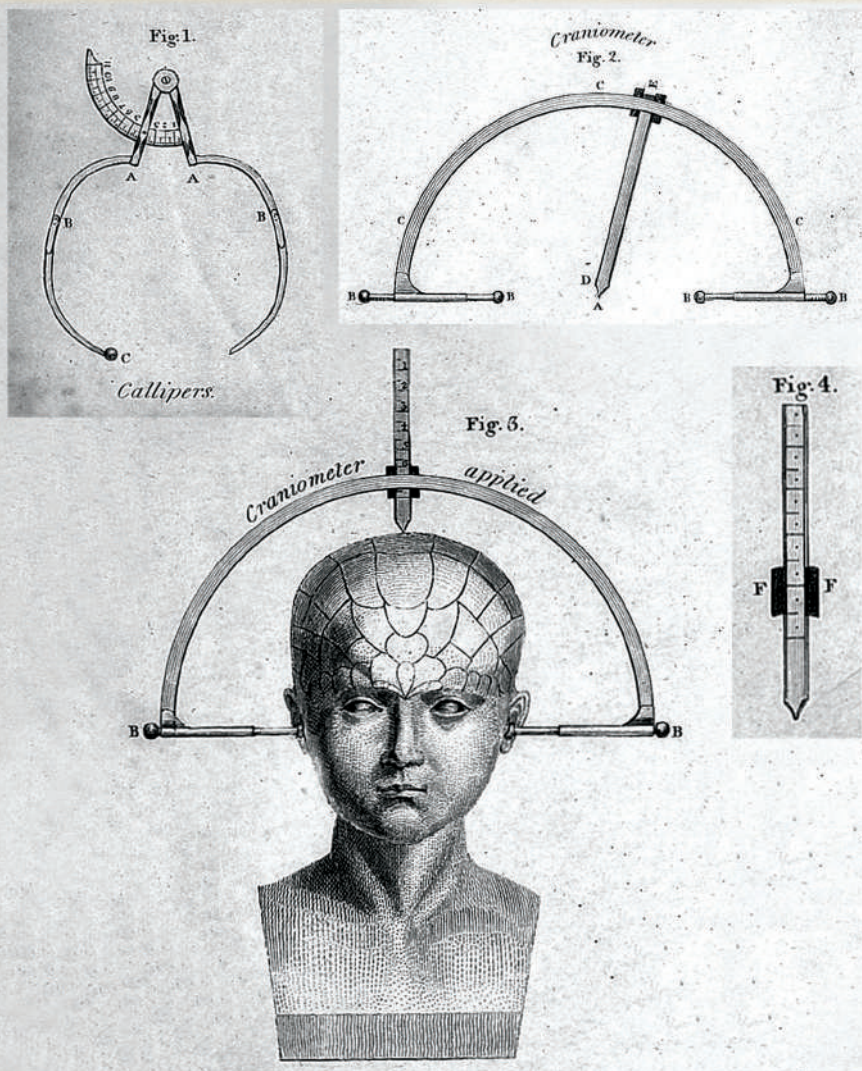
Japan's Akatsuki probe, currently in orbit around Venus, examines the planet in infrared radiation and sees a totally different world. Beneath its clouds, Venus has a thick carbon-dioxide atmosphere, 90 times as thick as Earth's, that produces an extreme greenhouse effect, heating the surface to a searing 850 degrees Fahrenheit. At this temperature, the surface glows brightly in infrared. What Akatsuki sees is therefore like a photographic negative, with all the usual notions of bright and dark reversed.

Here, we're looking at the night side of Venus. The illumination comes not from the sun but from the infrared energy of the planet and its lower atmosphere. Bright patches are areas where the upper clouds are thin, allowing the infrared to shine through; dark patches are areas of thick, high-altitude clouds. Seen in this light, Venus is a wild, stormy, dynamic place. Venus is very similar to Earth in size and composition, yet somehow it has turned into a hell planet. This planet could preview our own grim fate. It deserves a closer look.

Damned Lies

Eugenics and the myth of objectivity in statistics

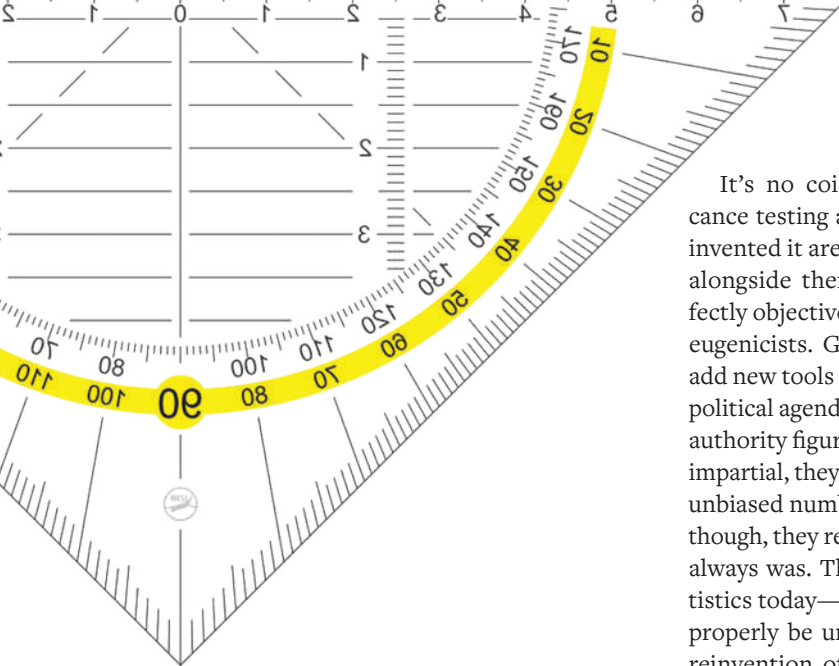
BY AUBREY CLAYTON



IN EARLY 2018, officials at University College London were shocked to learn that meetings organized by “race scientists” and neo-Nazis, called the London Conference on Intelligence, had been held at the college the previous four years. The existence of the conference was surprising, but the choice of location was not. UCL was an epicenter of the early 20th-century eugenics movement—a precursor to Nazi “racial hygiene” programs—due to its ties to Francis Galton, the father of eugenics, and his intellectual descendants and fellow eugenicists Karl Pearson and Ronald Fisher. In response to protests over the conference, UCL announced this June that it had stripped Galton’s and Pearson’s names from its buildings and classrooms. After similar outcries about eugenics, the Committee of Presidents of Statistical Societies renamed its annual Fisher Lecture, and the Society for the Study of Evolution did the same for its Fisher Prize. In science, these are the equivalents of toppling a Confederate statue and hurling it into the sea.

Unlike tearing down monuments to white supremacy in the American South, purging statistics of the ghosts of its eugenicist past is not a straightforward proposition. In this version, it’s as if Stonewall Jackson developed quantum physics. What we now understand as statistics comes largely from the work of Galton, Pearson, and Fisher, whose names appear in bread-and-butter terms like “Pearson correlation coefficient” and “Fisher information.” In particular, the beleaguered concept of “statistical significance,” for decades the measure of whether empirical research is publication-worthy, can be traced directly to the trio.

Ideally, statisticians would like to divorce these tools from the lives and times of the people who created them. It would be convenient if statistics existed outside of history, but that’s not the case. Statistics, as a lens through which scientists investigate real-world questions, has always been smudged by the fingerprints of the people holding the lens. Statistical thinking and eugenicist thinking are, in fact, deeply intertwined, and many of the theoretical problems with methods like significance testing—first developed to identify racial differences—are remnants of their original purpose, to support eugenics.



It's no coincidence that the method of significance testing and the reputations of the people who invented it are crumbling simultaneously. Crumbling alongside them is the image of statistics as a perfectly objective discipline, another legacy of the three eugenicists. Galton, Pearson, and Fisher didn't just add new tools to the toolbox. In service to their socio-political agenda, they established the statistician as an authority figure, a numerical referee who is by nature impartial, they claimed, since statistical analysis is just unbiased number-crunching. Even in their own work, though, they revealed how thin the myth of objectivity always was. The various upheavals happening in statistics today—methodological and symbolic—should properly be understood as parts of a larger story, a reinvention of the discipline and a reckoning with its origins. The buildings and lectures are the monuments to eugenics we can see. The less visible ones are embedded in the language, logic, and philosophy of statistics itself.

In science, these are the equivalents of toppling a Confederate statue and hurling it into the sea.

EUGENICS, FROM THE GREEK for “well born,” was the brainchild of Galton, a well-born Victorian gentleman scientist from a prominent English family. Thanks to his half-cousin Charles Darwin, Galton adopted the theory of evolution early, with a particular interest in applying it to humans. He posited that characteristics of successful people came from nature rather than nurture (a phrase he coined) and were therefore heritable, so breeding among elites should be encouraged by the state while breeding among those “afflicted by lunacy, feeble-mindedness, habitual criminality, and pauperism” discouraged. By being selective, like choosing the best traits of horses or cattle, he argued we could reshape the human species and create “a galaxy of genius.”

In his 1869 book *Hereditary Genius*, he tallied up famous people in various walks of life who also had famous relatives, to estimate how strongly natural ability could be expected to run in families. But these calculations also moved in predictably racist directions. In a chapter called “The Comparative Worth of Different Races,” he assessed that “the average intellectual standard of the Negro race is some two grades below our own,” which he attributed to heredity. Galton expressed a frequent loathing for Africans, whom

he called “lazy, palavering savages” in a letter he wrote to *The Times* advocating the coast of Africa be given to Chinese colonists so that they might “supplant the inferior Negro race.”

In the world of statistics, Galton is known as the inventor of the fundamental ideas of regression and correlation, related ways of measuring the degree to which one variable predicts another. He also popularized the concept that the spread of human abilities like intelligence tends to follow a normal distribution, or bell curve (an idea featured most prominently in the 1994 book *The Bell Curve*).

Galton’s ranking of the races was based on this distribution, which had only recently come into fashion in applied statistics. Since the early 1800s, it was known theoretically that whenever a large number of small independent increments were combined, the sums would follow a bell curve. If, for example, a crowd of people all stand together and each flip a fair coin to decide to take a step forward or backward, after a large number of coin tosses their positions will be distributed as a bell curve, mostly clustered toward the middle with a few in the extremes. At first, scientists used this in astronomy and geodesy, the study of the shape of the Earth, by assuming their measurement errors arose as the sum of a large number of tiny independent defects and should therefore follow a normal distribution. In the 1840s, Belgian social scientist Adolphe Quetelet discovered the shape in the distributions of people’s heights and chest sizes, leading him, with poetic flair, to imagine people as deviations from a common ideal, the “average man.” By smoothing out the errors, one could understand the true nature of this average person, like accurately estimating the position of Jupiter from a few observations.

One crucial assumption, though, was that the incremental probabilities were the same for all individuals. If, in our example, half the people use fair coins and the other half use lopsided coins with a 60 percent chance of coming up heads, eventually the group will split into a “bimodal” distribution, with two clusters corresponding to the two means. Instead of one “average man” there might actually be two. Quetelet understood this possibility and took pains to analyze his data in groups that could be considered sufficiently similar.



DARK PROPHETS Karl Pearson (left) referred to eugenics as “the directed and self-conscious evolution of the human race,” which he said Francis Galton (right) had understood “with the enthusiasm of a prophet.”

Are the science and the scientist so easily separable?

Quetelet's work with the normal curve had a profound impact on Galton because it provided a scale with which to grade people in every conceivable category. However, when he used the curve himself, Galton predicted that it would always apply to "men of the same race." (The idea of grouping only by race had some precedent; in the 1860s, French scientists Louis-Adolphe Bertillon and Gustave Lagneau found what they thought was a bimodal distribution in the heights of soldiers in Doubs, which they took as evidence that the population contained two distinct races.) So, Galton imagined one bell curve for white Europeans, one for Africans, one for Asians, and so on. Comparing curves to each other would show how substantial the racial differences were.

Racist attitudes like Galton's were not uncommon among the British aristocracy at the heights of colonialism, but Galton gave them scientific backing. He had the authority of a world traveler, in the tradition of Victorian naturalists like his half-cousin aboard the *Beagle*. His assessment of the supposed inferiority of others to white Britons was an important step toward enshrining these ideas as common knowledge, rationalizing the inestimable colonial violence in Asia, Africa, and the Americas.

Meanwhile, support for eugenics was sparse in Galton's day. Near the end of his life, Galton delivered

the lecture "Probability, the Foundation of Eugenics." Lamenting that the public had not yet come around on eugenics—in particular that people still married "almost anybody" without regard to their potential for superior breeding—he predicted public opinion would be swayed "when a sufficiency of evidence shall have been collected to make the truths on which it rests plain to all." When that happened, Galton foresaw a revolution, saying, "then, and not till then, will be a fit moment to declare a 'Jehad,' or Holy War against customs and prejudices that impair the physical and moral qualities of our race."

THE EUGENICS MOVEMENT'S greatest holy warrior was Karl Pearson, the person primarily recognized today as having created the discipline of mathematical statistics. Pearson was an intellectually driven and prolific scholar of many subjects. After graduating from Cambridge he studied physics, philosophy, law, literature, history, and political science before becoming a professor of applied mathematics at UCL. There he became exposed to Galton's ideas, and the two men had a fruitful collaboration for years. Pearson referred to eugenics as "the directed and self-conscious evolution of the human race," which he said Galton had understood "with the enthusiasm of a prophet."

Pearson had extreme, racist political views, and eugenics provided a language to argue for those positions. In 1900, he gave an address called “National Life from the Standpoint of Science,” in which he said, “My view—and I think it may be called the scientific view of a nation—is that of an organized whole, kept up to a high pitch of internal efficiency by insuring that its numbers are substantially recruited from the better stocks ... and kept up to a high pitch of external efficiency by contest, chiefly by way of war with inferior races.” According to Pearson, conflict between races was inevitable and desirable because it helped weed out the bad stock. As he put it, “History shows me one way, and one way only, in which a high state of civilization has been produced, namely the struggle of race with race, and the survival of the physically and mentally fitter race.”

Pearson considered the colonial genocide in America to be a great triumph because “in place of the red man, contributing practically nothing to the work and thought of the world, we have a great nation, mistress of many arts, and able ... to contribute much to the common stock of civilized man.” With an awareness some would criticize this as inhumane, he wrote in *The Grammar of Science*, “It is a false view of human solidarity, a weak humanitarianism, not a true humanism, which regrets that a capable and stalwart race of white men should replace a dark-skinned tribe which can neither utilize its land for the full benefit of mankind, nor contribute its quota to the common stock of human knowledge.”

Pearson the statistician had mathematical skills that Galton lacked, and he added a great deal of theoretical rigor to the field of statistics. In 1901, along with Galton and biologist Raphael Weldon, Pearson founded *Biometrika*, for decades the premiere publication for statistical theory (still highly esteemed today), with Pearson serving as editor until his death in 1936.

One of the first theoretical problems Pearson attempted to solve concerned the bimodal distributions that Quetelet and Galton had worried about, leading to the original examples of significance testing. Toward the end of the 19th century, as scientists began collecting more data to better understand the process of evolution, such distributions began to crop up more often. Some particularly unusual measurements of crab shells collected by Weldon inspired Pearson to wonder,

exactly how could one decide whether observations were normally distributed?

Before Pearson, the best anyone could do was to assemble the results in a histogram and see whether it looked approximately like a bell curve. Pearson’s analysis led him to his now-famous chi-squared test, using a measure called X^2 to represent a “distance” between the empirical results and the theoretical distribution. High values, meaning a lot of deviation, were unlikely to occur by chance if the theory were correct, with probabilities Pearson computed. This formed the basic three-part template of a significance test as we now understand it:

1. Hypothesize some kind of distribution in the data (e.g., “All individuals are of the same species, so their measurements should be normally distributed”). Today this would be referred to as a “null hypothesis,” a straw man standing in opposition to a more interesting research claim, such as two populations being materially different in some way.
2. Use a test statistic like Pearson’s X^2 to measure how far the actual observations are from that prediction.
3. Decide whether the observed deviation is enough to knock down the straw man, measured by the probability, now called the “ p -value,” of getting a statistic at least that large by chance. Typically, a p -value less than 5 percent is considered reason enough to reject the null hypothesis, with the results deemed “statistically significant.” In Pearson’s usage, the word “significant” didn’t necessarily have connotations of importance or magnitude but was simply the adjective form of “signify,” meaning “to be indicative of.” That is, experimental results were significant of a hypothesis if they indicated the hypothesis was true to some degree of certainty.

Applying his tests led Pearson to conclude that several datasets like Weldon’s crab measurements were not truly normal. Racial differences, however, were his main interest from the beginning. Pearson’s statistical work was inseparable from his advocacy for eugenics. One of his first example calculations concerned a set of skull measurements taken from graves of the Reihengräber culture of Southern Germany in the fifth to seventh centuries. Pearson argued that an asymmetry



THE GATEKEEPER Ronald Fisher's eugenicist proposals were, in some cases, aimed at the statistical academy. In *The Eugenics Review*, Fisher wrote, "A profession must have power to select its own members, rigorously to exclude all inferior types."

in the distribution of the skulls signified the presence of two races of people. That skull measurements could indicate differences between races, and by extension differences in intelligence or character, was axiomatic to eugenicist thinking. Establishing the differences in a way that appeared scientific was a powerful step toward arguing for racial superiority.

Around the same time that Pearson was describing his method for recognizing non-normal data by writing, "The asymmetry may arise from the fact that the units grouped together in the measured material are not really homogeneous," he was also describing his theory of nations by saying, "The nation organized for the struggle must be a homogeneous whole, not a mixture of superior and inferior races." So, the word "homogeneous," linking the statistical statement to the one from eugenics, had a particularly charged meaning for Pearson, with connotations of racial purity. Homogeneity in data and what it indicated about homogeneity of people had unavoidably racist undertones.

In another typical example, in 1904 he published a study in *Biometrika* that, using a technique of his invention called "tetrachoric correlation," reported roughly the same correlation among 4,000 pairs of siblings for inherited traits like eye color as it did for mental qualities like "vivacity," "assertiveness," and "introspection." He concluded this meant they were all equally hereditary, that we are "literally forced, to the general conclusion that ... we inherit our parents' tempers, our parents' conscientiousness, shyness and ability, even as we inherit their stature, forearm and span." He ended with a sweeping assertion about the failure of British stock to keep pace with that of America and Germany, advising that "intelligence can be aided and be trained, but no training or education can create it. You must breed it, that is the broad result for statecraft which flows from the equality in inheritance of the psychical and the physical characters in man." In other words, he measured two things—how often siblings' bodies were alike and how often their personalities were—and, finding these measurements to be approximately equal, concluded the qualities must originate in the same way, from which he jumped to dramatic, eugenicist conclusions.

The same year, Galton created the Eugenics Record Office, later renamed the Galton Laboratory

for National Eugenics. While working in Galton's Lab, Pearson founded another journal, *Annals of Eugenics* (known today as the *Annals of Human Genetics*), where he could make the case for eugenics even more explicitly. The first such argument, in Volume I of the new journal in 1925, concerned the influx of Jewish immigrants into the United Kingdom fleeing pogroms from eastern Europe. Pearson predicted that if these immigrants kept coming, they would "develop into a parasitic race."

The statistical argument was a one-two punch: by examining a large number of Jewish immigrant children for various physical characteristics, combined with surveys of the conditions of their home lives and intelligence assessments provided by their teachers, Pearson claimed to establish (1) that the children (especially girls) were on average less intelligent than their non-Jewish counterparts, and (2) their intelligence was not significantly correlated with any environmental factor that could be improved, such as health, cleanliness, or nutrition. As Pearson concluded, "We have at present no evidence at all that environment without selection is capable of producing any direct and sensible influence on intelligence; and the argument of the present paper is that into a crowded country only the superior stocks should be allowed entrance, not the inferior stocks in the hope—unjustified by any statistical inquiry—that they will rise to the average native level by living in a new atmosphere." The journal was immediately referenced by people looking to support their anti-Semitism scientifically. Arthur Henry Lane, author of *The Alien Menace*, said Pearson's conclusions were "of such profound importance as affecting the interests and welfare of our nation, that all men of British race and especially all statesmen and politicians should obtain '*The Annals of Eugenics*.'"

The most consistent hallmark of someone with an agenda, it seems, is the excessive denial of having one. In introducing the study of the Jewish children, Pearson wrote, "We believe there is no institution more capable of impartial statistical inquiry than the Galton Laboratory. We have no axes to grind, we have no governing body to propitiate by well-advertised discoveries; we are paid by nobody to reach results of a given bias ... We firmly believe that we have no political, no religious and no social prejudices, because we find ourselves abused

incidentally by each group and organ in turn. We rejoice in numbers and figures for their own sake and, subject to human fallibility, collect our data—as all scientists must do—to find out the truth that is in them." By slathering it in a thick coating of statistics, Pearson gave eugenics an appearance of mathematical fact that would be hard to refute. Anyone looking to criticize his conclusions would have to first wade through hundreds of pages of formulas and technical jargon.

When Galton died in 1911, he left the balance of his considerable fortune to UCL to finance a university eugenics department. Pearson, then serving as director of the Galton Lab, was named by Galton as the first Galton Chair in National Eugenics, a position that exists today as the Galton Chair of Genetics. An offshoot of the UCL eugenics department would later become the world's first department of mathematical statistics. In his dual roles as lab director and professor, Pearson had tremendous power over the first crop of British statisticians. Major Greenwood, Pearson's former student, once described him as "among the most influential university teachers of his time."

The work Pearson did during that period was the continuation of Galton's mission to broadcast the "truths" of eugenics in preparation for an overhaul of social norms. This would mean interfering in the intimate relationships within families. Pearson said, "I fear our present economic and social conditions are hardly yet ripe for such a movement; the all-important question of parentage is still largely felt to be solely a matter of family, and not of national importance ... From the standpoint of the nation we want to inculcate a feeling of shame in the parents of a weakling, whether it be mentally or physically unfit."

Given the reactions this was bound to provoke, maintaining the veneer of objectivity was crucial. Pearson claimed he was merely using statistics to reveal fundamental truths about people, as unquestionable as the law of gravity. He instructed his university students, "Social facts are capable of measurement and thus of mathematical treatment, their empire must not be usurped by talk dominating reason, by passion displacing truth, by active ignorance crushing enlightenment." The subtitle of the *Annals of Eugenics* was Darwin's famous quote, "I have no Faith in anything short of actual measurement and the rule of three."

Most scientists now understand that the data do not speak for themselves and never have.

In Pearson's view, it was only by allowing the numbers to tell their own story that we could see these truths for what they were. If anyone objected to Pearson's conclusions, for example that genocide and race wars were instruments of progress, they were arguing against cold, hard logic and allowing passion to displace truth.

RONALD FISHER, Pearson's successor both as the Galton Chair of Eugenics at UCL and as editor of the *Annals of Eugenics*, is the only other person with a legitimate claim as the most influential statistician of the 20th century. Fisher was incredibly influential in biology, too. Primarily, his 1930 book *The Genetical Theory of Natural Selection* helped reconcile Mendelian genetics with Darwinian evolution, the project of evolutionary biology called the "modern synthesis." For these and other contributions, he was widely celebrated then and now. In 2011, Richard Dawkins called him "the greatest biologist since Darwin."

But before he was a biologist or a statistician, Fisher was a eugenicist. He became a convert while an undergraduate at Cambridge, where he encountered Galton and Pearson's work and helped form the Cambridge Eugenics Society, with Fisher as

student chair of the council. Between 1912 and 1920, he wrote 91 articles for Galton's journal, *The Eugenics Review*. In one of his earliest publications, an essay called "Some Hopes of a Eugenist," he wrote, "The nations whose institutions, laws, traditions and ideals, tend most to the production of better and fitter men and women, will quite naturally and inevitably supplant, first those whose organization tends to breed decadence, and later those who, though naturally healthy, still fail to see the importance of specifically eugenic ideas."

This eugenics-flavored nationalism would be a running theme throughout Fisher's career. The final five chapters of *The Genetical Theory of Natural Selection*, comprising about a third of the book, contain a manifesto on the fall of nations, with sections including "The mental and moral qualities determining reproduction," "Economic and biological aspects of class distinctions," and "The decay of ruling classes." Fisher claimed the higher fertility rates among the lower classes would bring down any civilization, including the British Empire, so he proposed a system of limits and disincentives against large families of low social status or immigrants.

By Fisher's time, eugenics had gained momentum as part of larger programs for



DOWN WITH EUGENICS Like the removal of Confederate statues from public places in the South, universities and science associations have removed the names of Galton, Pearson, and Fisher from buildings and science prizes.

social reform in the early 20th century. The movement met fierce resistance, particularly from religious institutions, and never really achieved prominence in the U.K. British eugenicists succeeded at turning only some of their ideas into reality, most notably immigration restrictions and one especially awful domestic policy, the Mental Deficiency Act of 1913, which made it so anyone deemed “feeble-minded” or “morally defective” could be involuntarily committed. Because the standards for who qualified were notoriously vague, at one time there were upward of 65,000 people living in such state-operated “colonies.” In response to the act, G.K. Chesterton wrote *Eugenics and Other Evils*, in which he derided eugenicists for interfering with people’s lives, “as if one had a right to dragoon and enslave one’s fellow citizens as a kind of chemical experiment.”

Meanwhile, Galton’s movement spread to the United States, primarily through the efforts of Harvard professor Charles Davenport, a co-editor of *Biometrika*, who learned about eugenics and its statistical arguments

directly from Galton and Pearson. In 1910, Davenport founded the Eugenics Record Office in Cold Spring Harbor, New York, which, like Galton’s laboratory, collected data on social and physical traits from several hundred thousand individuals. Applying Galton and Pearson’s techniques, Davenport wrote numerous publications arguing the dangers of interracial marriage and immigration from countries of “inferior” stock. Davenport founded the Galton Society of America, an organization of eugenicists in science with influential connections. They used their positions of power to direct American research in the 1920s and ’30s and to lobby, successfully, for measures like marriage prohibitions, restrictions on immigration, and forced sterilization of the mentally ill, physically disabled, or anyone else deemed a drain on society.

Today, most people associate eugenics with Nazi Germany, but it was from these American eugenicists and Galton-followers that the Nazis largely took their inspiration. Adolf Hitler once said, “I have studied with

AP

great interest the laws of several American states concerning prevention of reproduction by people whose progeny would, in all probability, be of no value or be injurious to the racial stock,” and in a fan letter to Madison Grant, co-founder of the Galton Society of America, Hitler referred to Grant’s book *The Passing of the Great Race* as “my bible.”

Similar sterilization policies would have been illegal in the U.K. at the time, but Fisher and other British eugenicists were working to change that. The eerie similarity to Nazi programs was not coincidental. In 1930, Fisher and other members of the British Eugenics Society formed the Committee for Legalizing Eugenic Sterilization, which produced a propaganda pamphlet arguing the benefits of sterilizing “feeble minded high-grade defectives.” Fisher contributed a supporting statistical analysis, based on data collected by American eugenicists demonstrating what they claimed was the degree of heredity for intellectual disabilities.

To strengthen their arguments with additional data, the Society reached out directly to Nazi eugenicist Ernst Rüdin, a chief contributor to the pseudoscientific justifications for the atrocities of Hitler’s Germany. Rüdin in turn expressed his admiration for the work of Fisher’s Committee. Fisher continued to have disturbingly close ties to Nazi scientists even after the war. He issued public statements to help rehabilitate the image of Otmar Freiherr von Verschuer, a Nazi geneticist and advocate of racial hygiene ideas who had been a mentor to Josef Mengele, who conducted barbaric experiments on prisoners in Nazi camps. In von Verschuer’s defense, Fisher wrote, “I have no doubt also that the [Nazi] Party sincerely wished to benefit the German racial stock, especially by the elimination of manifest defectives, such as those deficient mentally, and I do not doubt that von Verschuer gave, as I should have done, his support to such a movement.”

In 1950, in response to the Holocaust, the United Nations body UNESCO issued a statement called “The Race Question” to condemn racism on scientific grounds. Fisher wrote a dissenting opinion, which UNESCO included in a revised version in 1951. He claimed the evidence showed human groups differ profoundly “in their innate capacity for intellectual and emotional development” and concluded that the

“practical international problem is that of learning to share the resources of this planet amicably with persons of materially different nature.”

As a statistician, Fisher is personally responsible for many of the basic terms that now make up the standard lexicon, such as “parameter estimation,” “maximum likelihood,” and “sufficient statistic.” But the backbone of his contributions was significance testing. Fisher’s 1925 textbook *Statistical Methods for Research Workers*, containing statistical recipes for different problems, introduced significance testing to the world of science and became such the industry standard that anyone not following one of his recipes would have difficulty getting published. Among Fisher’s most prominent disciples were statistician and economist Harold Hotelling, who in turn influenced two Nobel Prize-winning economists, Kenneth Arrow and Milton Friedman, and George Snedecor, who founded the first academic department of statistics in the U.S.

Fisher promoted significance testing as a general framework for deciding all manner of questions, claiming its logic was “common to all experimentation.” Applying the same template from Pearson’s chi-squared test to other kinds of problems, Fisher supplied many of the tests we still use today, like Fisher’s F-test, ANOVA (analysis of variance), and Fisher’s exact test. Many of Fisher’s contributions were, therefore, just derivations of the mathematical formulas needed for these tests. In the process, his methods made possible whole new research hypotheses: questions like whether two variables were correlated, or whether multiple populations all had the same mean.

Like Pearson, Fisher maintained that he was only ever following the numbers where they took him. Significance testing, for Fisher, was a way of communicating statistical findings that was as unassailable as a logical proof. Regarding the method, he wrote, “The feeling induced by a test of significance has an objective basis in that the probability statement on which it is based is a fact communicable to, and verifiable by, other rational minds.” As he wrote in 1932, “Conclusions can be drawn from data alone ... if the questions we ask seem to require knowledge prior to these, it is because ... we have been asking somewhat the wrong questions.”

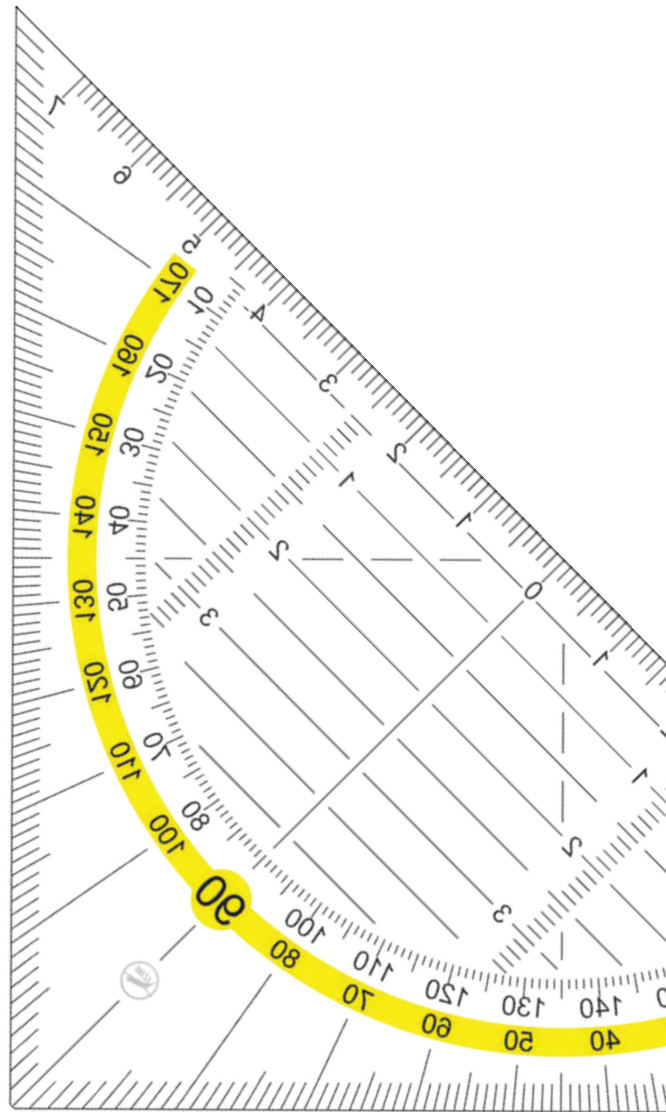
To get rid of the stain of eugenics, statistics needs to free itself from the ideal of being perfectly objective.

TODAY, IN RESPONSE TO the protests over Galton, Pearson, and Fisher, defenders have argued that lectures and buildings are named to honor scientific contributions, not people. Statistics professors Joe Guinness of Cornell, Harry Crane of Rutgers, and Ryan Martin of North Carolina State wrote in a comment on the Fisher lecture controversy that “we must recall that the esteem of science is maintained by a collective trust that its achievements are independent of the virtues and vices of the people who achieve them, that recognition is not granted or revoked on the pretense of personal friendship or political positioning, and that we can at once celebrate and benefit from scientific contributions while disagreeing wholeheartedly with the personal beliefs of the scientists responsible for them.”

But are the science and the scientist so easily separable?

Without Fisher around to advocate for it, the dominance of significance testing is waning. Last year, a letter signed by over 800 scientists called for an end to the concept of statistical significance, and the leadership of the American Statistical Association issued a blunt decree: “Don’t say ‘statistically significant.’” The heart of the problem with significance testing is that making binary decisions about homogeneity was never a meaningful statistical task. With enough data, looked at closely enough, some inhomogeneities and statistically significant differences will always emerge. In the real world, data are always signaling something. It just may not be clear what.

In 1968, psychologists David Lykken and Paul Meehl of the University of Minnesota demonstrated this empirically with an analysis of 57,000 questionnaires filled out by Minnesota high school students. The surveys included a range of questions about the





“MY BIBLE” Hitler said he “studied with great interest” the eugenics theories of Galton and his followers. In a letter to Madison Grant, co-founder of the Galton Society of America, Hitler referred to Grant’s book *The Passing of the Great Race* as “my bible.”

students’ families, leisure activities, attitudes toward school, extracurricular organizations, etc. Meehl and Lykken found that, of the 105 possible cross-tabulations of variables, every single association was statistically significant, and 101 (96 percent) had p -values less than 0.000001. So, for example, birth order (oldest, middle, youngest, only child) was significantly associated with religious views, and with family attitudes toward college, interest in cooking, membership in farm youth clubs, occupational plans after school, and so on. But, as Meehl emphasized, these results were not obtained purely by chance: “They are facts about the world, and with $N = 57,000$ they are pretty stable ... Drawing theories from a pot and associating them whimsically with variable pairs would yield an impressive batch of [null hypothesis]-refuting ‘confirmations.’” That is, any one

of these 105 findings could, according to standard Pearsonian and Fisherian practice, be taken as evidence of inhomogeneity and a significant refutation of a null hypothesis.

Meehl became one of the most outspoken critics of significance testing. In 1978, when the method had by then been the standard for over 50 years, he wrote that “Sir Ronald [Fisher] has befuddled us, mesmerized us, and led us down the primrose path,” and that “the almost universal reliance on merely refuting the null hypothesis as the standard method for corroborating substantive theories in the soft areas is a terrible mistake, is basically unsound, poor scientific strategy, and one of the worst things that ever happened in the history of psychology.” He described his call to get rid of significance testing as “revolutionary, not reformist.”

Similar criticism of the use of statistics in science has a long history. As first argued by psychologist Edwin Boring in 1919, a scientific hypothesis is never just a statistical hypothesis—that two means in the population are different, that two variables are correlated, that a treatment has some nonzero effect—but an attempt at explaining why, by how much, and why it matters. The fact that significance testing ignores this is what economists Deirdre McCloskey and Stephen Ziliak in their 2008 book *The Cult of Statistical Significance* called the “sizeless stare of statistical significance.” As they put it, “Statistical significance is not a scientific test. It is a philosophical, qualitative test. It does not ask how much. It asks ‘whether,’ ”—as in, whether an effect or association simply exists. “Existence, the question of whether, is interesting,” they said, “but it is not scientific.”

Despite the objections, the practice is still very much the norm. When we hear that meeting online is associated with greater happiness than meeting in person, that some food is associated with a decreased risk of cancer, or that such-and-such educational policy led to a statistically significant increase in test scores, and so on, we’re only hearing answers to the “question of whether.” What we should be asking is what causal mechanism explains the difference, whether it can be applied elsewhere, and how much benefit could be obtained from doing so.

In the context of eugenics, it’s understandable why Galton, Pearson, and Fisher would care so much about questions of existence. For the purposes of eugenic discrimination, it was enough to state that distinct racial subgroups existed or there was a “significant” correlation between intelligence and cleanliness or a “significant” difference in criminality, fertility, or disease incidence between people of different socioeconomic classes. The first hypotheses were taxonomic: whether individuals could be considered to be of the same species, or whether people were of the same race. The separation was everything—not how much, what else might explain it, or why it mattered, just that it was there. Significance testing did not spring fully formed from the heads of these men. It was crafted and refined over the years specifically to articulate evolutionary and eugenicist arguments. Galton, Pearson, and Fisher

the eugenicists needed a quantitative way to argue for the existence of such differences, and Galton, Pearson, and Fisher the statisticians answered the call with significance testing.

Their attitude that statistical analysis reveals truth without help from the statistician is likewise disintegrating. Most scientists now understand that the data do not speak for themselves and never have. Observations are always possible to interpret in multiple ways, and it’s up to the scientist and the larger community to decide which interpretation best fits the facts. Sampling error is not the only kind of error that matters in significance testing. Bias can result from how an experiment is conducted and how outcomes are measured.

Nathaniel Joselson is a data scientist in healthcare technology, whose experiences studying statistics in Cape Town, South Africa, during protests over a statue of colonial figure Cecil John Rhodes led him to build the website “Meditations on Inclusive Statistics.” He argues that statistics is overdue for a “decolonization,” to address the eugenicist legacy of Galton, Pearson, and Fisher that he says is still causing damage, most conspicuously in criminal justice and education. “Objectivity is extremely overrated,” he told me. “What the future of science needs is a democratization of the analysis process and generation of analysis,” and that what scientists need to do most is “hear what people that know about this stuff have been saying for a long time. Just because you haven’t measured something doesn’t mean that it’s not there. Often, you can see it with your eyes, and that’s good enough.”

To get rid of the stain of eugenics, in addition to repairing the logic of its methods, statistics needs to free itself from the ideal of being perfectly objective. It can start with issues like dismantling its eugenicist monuments and addressing its own diversity problems. Surveys have consistently shown that among U.S. resident students at every level, Black/African-American and Hispanic/Latinx people are severely underrepresented in statistics. But to understand the full depth of what that means about the discipline requires navigating a complex web of attitudes, expectations, symbols, and human emotions. No summary number could do it justice. Daniela Witten of the University of Washington statistics department, the member of the awards committee for the COPSS Fisher Lecture who instigated

We cannot escape the fact that statistics is a human enterprise subject to human desire, prejudice, consensus, and interpretation.

the movement to change its name, told me, “We need to take an intellectual stance, an academic stance, and a historical stance, but we also need to consider the fact that there are real-life people involved.”

Fisher’s eugenicist proposals were, in some cases, aimed directly at the statistical academy. In 1917, he wrote in *The Eugenics Review*, “A profession must have power to select its own members, rigorously to exclude all inferior types, who would lower both the standard of living and the level of professional status. In this process the eugenist sees a desirable type, selected for its valuable qualities, and protected by the exclusive power of its profession in a situation of comparative affluence.” Fisher acted as a gatekeeper for the profession of statistics, encouraging what he considered to be the right types to enter, and as his words make clear, he considered the right type of statistician to be one most like himself. Galton and Pearson, similarly, when they imagined the utopia brought about through eugenics, pictured a society of exclusively Galtons and Pearsons.

Emma Benn is a professor of biostatistics at Mount Sinai and an advocate for changing the name of the Fisher Lecture. When I spoke with Benn, who is African-American, she was quick to point out the controversy over the lecture was about issues larger than Fisher. “Let’s reevaluate what we think is a great contribution to the field,” she said. “Yes, we can address specifically Fisher, but I hope that that would help us delve deeper into, ‘What does it mean in science to belong?’ ‘How does knowing about these things affect our scientific identity?’ When we have this conversation about Fisher, or we have a conversation about race, then all of a sudden it’s this intellectual exercise that removes people from having to consider how people like me feel in this field.”

Addressing the legacy of eugenics in statistics will require asking many such difficult questions. Pretending to answer them under a veil of objectivity serves to dehumanize our colleagues, in the same way the dehumanizing rhetoric of eugenics facilitated discriminatory practices like forced sterilization and marriage prohibitions. Both rely on distancing oneself from the people affected and thinking of them as “other,” to rob them of agency and silence their protests.

How an academic community views itself is a useful test case for how it will view the world. Statistics,

steeped as it is in esoteric mathematical terminology, may sometimes appear purely theoretical. But the truth is that statistics is closer to the humanities than it would like to admit. The struggles in the humanities over whose voices are heard and the power dynamics inherent in academic discourse have often been destructive, and progress hard-won. Now that fight may have been brought to the doorstep of statistics.

In the 1972 book *Social Sciences as Sorcery*, Stanislaw Andreski argued that, in their search for objectivity, researchers had settled for a cheap version of it, hiding behind statistical methods as “quantitative camouflage.” Instead, we should strive for the moral objectivity we need to simultaneously live in the world and study it. “The ideal of objectivity,” Andreski wrote, “requires much more than an adherence to the technical rules of verification, or recourse to recondite unemotive terminology: namely, a moral commitment to justice—the will to be fair to people and institutions, to avoid the temptations of wishful and venomous thinking, and the courage to resist threats and enticements.”

Even if we use the most technical language, we cannot escape the fact that statistics is a human enterprise subject to human desire, prejudice, consensus, and interpretation. Andreski challenged us to be honest about factors that influence us and avoid serving unjust masters who would push us toward the conclusions that suit them best. We need the discipline of statistics to be inclusive, not only because it’s the right thing to do and because it enlarges the pool of talented statisticians, but also because it’s the best way to eliminate our collective blind spots. We should try to be objective, not in the impossible sense that Galton, Pearson, and Fisher claimed granted them authority, but in the way they failed to do when they let the interests of the ruling class dictate the outcome of their research before it began. ☺

AUBREY CLAYTON is a mathematician living in Boston and the author of the forthcoming book *Bernoulli’s Fallacy*.



ALICE AND BOB MEET THE WALL OF FIRE

THE BIGGEST IDEAS IN SCIENCE FROM *QUANTA*

"An exploration of the universe with all its
mystery and wonder and starlit dazzle."

Deborah Blum

Pulitzer Prize-winning science journalist

EDITED BY **THOMAS LIN**
FOREWORD BY **SEAN CARROLL**



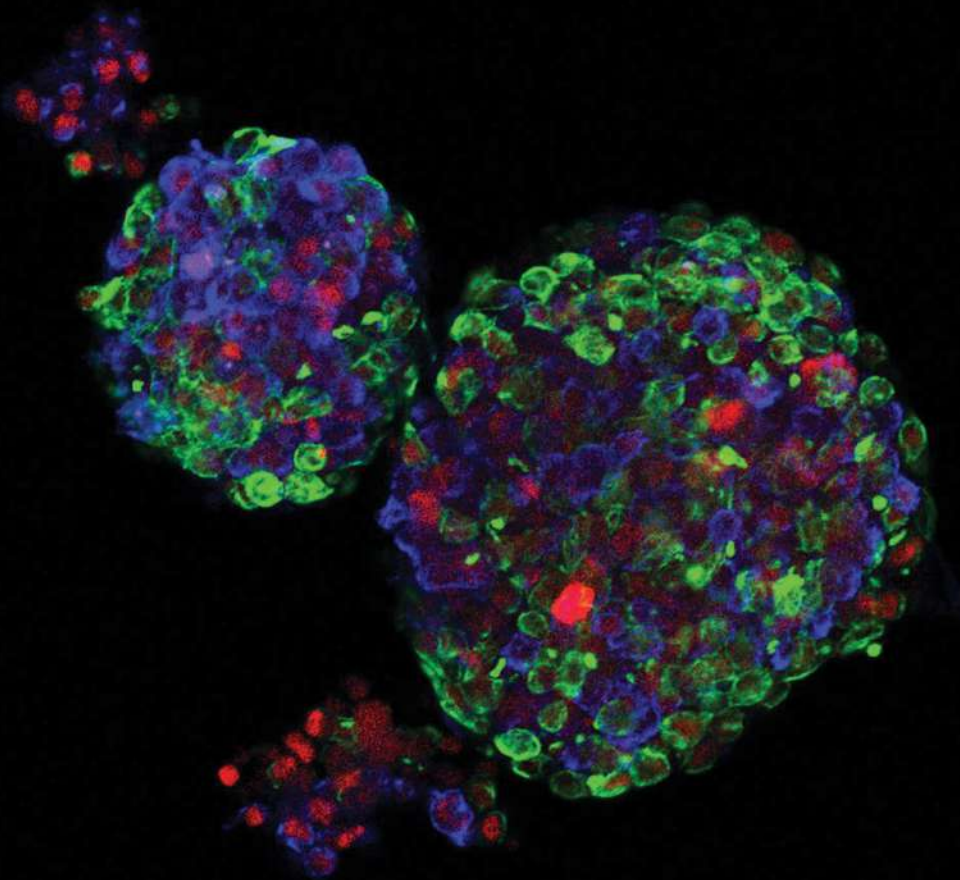
AVAILABLE NOW AT
AMAZON, BARNES & NOBLE, and POWELL'S

"If you're a science and data nerd like me, you
may be interested in 'Alice and Bob Meet the
Wall of Fire' and 'The Prime Number Conspiracy'
from @QuantaMagazine and @7homeslin."

@BillGates



BIOLOGY+BEYOND



Explore the frontiers of biology and genetics
on Nautilus Channels with Cold Spring Harbor Laboratory
one of the world's leading private research institutions

cshl.nautil.us



NAUTILUS



Cold Spring Harbor Laboratory

The Universe Has Made Almost All the Stars It Will Ever Make

Black holes are cosmic dimmers

BY CALEB SCHARF



OUR HUMAN WORLD is soaked in light. For starters there are the 100,000 trillion photons arriving every second at every square centimeter of Earth's dayside surface, after racing here from the outer envelope of a natural giant thermonuclear reactor we call the sun. There are also the photons that zip every which way through any cubic centimeter of open space. Some of these are the microwave leftovers from the hot Big Bang over 13 billion years ago, others are the photons produced in distant stars and innumerable astrophysical events strewn across the cosmos.

We're also bathed in locally-sourced, artisanal electromagnetic radiation. We warm, squishy humans are potent infrared beacons. Our fancy chemical metabolism sheds energy as heat, radiating photons off into the environment. If you could switch on goggles sensitive to infrared wavelengths of the electromagnetic spectrum you would find a world brilliantly aglow: from your self-generated light to the light blazing from your dogs, cats, pet parrots, and even the tiny muscles of frantically flapping insects.¹

Somehow a galaxy that spans tens of thousands of light-years is intimately related to a microscopic dot at its center.

Yet as we look beyond, into the cosmos, it becomes more and more apparent that our light-saturated existence is perhaps a little unusual. One of the biggest clues to this fact stares us in the face every time the sun sets and the sky darkens. If we lived in a truly endless and unchanging universe then we might expect there to be galaxies of stars in every single direction we looked, all stacked up in infinite progression so that there would be no place without visible light.

In cosmology this is known as Olbers' paradox, after work by the German astronomer Heinrich Olbers in 1823. Despite doing a decent job at mathematically phrasing a long-recognized puzzle, Olbers himself failed to offer a good solution for why the celestial sphere was mostly dark, leaving room for none other than Edgar Allen Poe to put things onto the right track in 1848. Poe's qualitative insight was that perhaps the cosmos was simply not old enough to fill the sky with light.

The modern resolution to the paradox contains some subtleties, but it does indeed mostly come down to the fact that we do not live in an endless and unchanging universe. Not only does the universe have a finite age, it has a complex history of making stars (with finite lifespans), and it is undergoing an expansion that dilutes the intensity of light that reaches us from distant places. Consequently, our sky is not uniformly bright to our eyes, and most of the cosmos is photon-starved compared to our everyday circumstances.

The story doesn't quite end there though, because stellar history has some curious kinks in it, associated with the actual formation of stars in the first place. While we have a pretty robust (although still incomplete) understanding of the basic physical drivers and processes that lead to the existence of individual stars or groups of stars—beginning with the gravitational agglomeration and collapse of interstellar matter—when it comes to entire populations of stars in galaxies things are rather trickier.

It becomes more and more apparent that our light-saturated existence is perhaps a little unusual.



Research over the past 30 or so years has revealed that the formation of stars across the universe reached an extended peak of activity roughly 10 to 11 billion years ago.² Since that epoch, while new stars are certainly still being produced, the rate of production has lessened dramatically. So much so that it appears that the great majority of stars that the universe will ever make—perhaps 95 percent of them—have already been made.³ The future is one of ever-dwindling numbers of stellar newborns, punctuated by occasional flurries as galaxies merge or other triggering events occur.



But there's a big puzzle here. Exactly what puts a cap on the number of stars the universe has made and will ever make? This question has long been a subject of intense astrophysical debate, particularly in relation to the stellar composition of individual galaxies. For example, our current cosmological paradigm (or at least the one that most scientists subscribe to) is that we live in a universe dominated by dark matter, and in a dark matter universe the biggest galaxies should have formed the most recently,⁴ being assembled by the hierarchical, gravitationally driven merger of smaller systems. Yet if you examine very large, massive galaxies you find that they tend to be composed of older stars, suggesting that they've already sat around in their dotage for a very long time.

To try to explain this, astronomers invoke the idea of “quenching,” where something acts to suppress or shut down the formation of new stars across galaxies. Not surprisingly, you need a pretty potent mechanism to quench anything on these scales, and among the most plausible culprits are the supermassive black holes that exist at the core of most galaxies and which can flood the space around them with photons and particles emitted from material as it screeches toward their event horizons. That outward transfer of energy can, quite literally, blow away the interstellar gas that would otherwise cool and clump into new stars.





The precise details of how this might work are certainly not yet fully understood. But there are new tantalizing clues in the fact that the masses of supermassive black holes appear to correlate with the mass of stars contained in their host galaxies.⁵ That is pretty shocking because even a supermassive black hole a billion times the mass of our sun only occupies a volume similar to that of our solar system. So somehow a galaxy that spans tens of thousands of light-years is intimately related to what is, in effect, a microscopic dot at its center.

One proposed explanation is that a kind of pulsing feedback system exists. If the black holes grow by gobbling up the same inflow of interstellar matter that makes new stars, this can trigger those floods of outgoing energy, simultaneously pushing the black hole food away and quenching star formation across an entire galaxy—keeping the masses of the holes and the total number of stars in a lock-step growth throughout their history.

And therein lies one of the oddest features of black holes. Despite being “one-way streets” in the cosmos—ingrown warpages of space and time sheathed by event horizons that allow nothing to return—black holes can also power some of the most luminous and far-reaching phenomena in the observable universe. Phenomena that have, in turn, likely acted to profoundly limit how many stars the universe can have; to play a role in quenching the accumulated light of the cosmos. It’s an old saying that you can’t have light without darkness, and for the universe it’s also very much true that you can’t have darkness without light. ☺



CALEB SCHARF is an astrophysicist, the director of astrobiology at Columbia University in New York, and a founder of yhousenyc.org, an institute that studies human and machine consciousness. His latest book is *The Zoomable Universe: An Epic Tour Through Cosmic Scale, from Almost Everything to Nearly Nothing*.

REFERENCES

1. Heinrich, B. Thermoregulation in endothermic insects. *Science* **185**, 747-756 (1974).
2. Madau, P. & Dickinson, M. Cosmic star-formation history. *Annual Review of Astronomy and Astrophysics* **52**, 415-486 (2014).
3. Sobral, D., *et al.* A large H α survey at $z = 2.23, 1.47, 0.84$ and 0.40 : the 11 Gyr evolution of star-forming galaxies from HiZELS. *Monthly Notices of the Royal Astronomical Society* **428**, 1128-1146 (2013).
4. Man, A. & Belli, S. Star formation quenching in massive galaxies. *Nature Astronomy* **2**, 6950697 (2018).
5. Stephens, T. How galaxies die: New insights into the quenching of star formation. news.ucsc.edu (2020).





Eels Don't Have Sex Until the Last Year of Their Life

Why eels are one strange fish

BY STEVE PAULSON

FISHING FOR EELS was a primal childhood experience for Patrik Svensson. On summer nights his father would take him down to a small stream near their home in Sweden. It was a magical place, surrounded by willow trees, with bats swooping through the moonlight. They barely talked as they set their fishing lines along the bank. “It was what me and my father did together. We fished for eels,” he recalls. Back home, Patrik’s mother would toss their catch in the frying pan, but the eels still squirmed and wriggled even after they were chopped up, with no heads. “I always found it fascinating and a little scary,” he says. “It made me think, what’s really the difference between life and death?”

TATIANA BELOVA / SHUTTERSTOCK

That's just one of the many questions that haunted Svensson for decades. And he's far from alone in his obsession. The eel is one of the most mysterious creatures on Earth, and for centuries it confounded scientists, from Aristotle to Freud. No one could figure out how—or where—they reproduced. Or whether there were actually male and female eels. Or how they managed to transform from saltwater to freshwater animals and then back to saltwater “silver eels” at the end of their lives. Or even whether the eel was a fish or some kind of water snake.

Svensson, a soft-spoken journalist with a keen sense of wonder and a taste for philosophical musings, writes about his long fascination with this strange animal in *The Book of Eels*. A blend of natural history and memoir, the book is a beguiling chronicle of the many people who've tried to uncover the eel's secrets.

I reached Svensson at his home in Malmo, Sweden.

What exactly is “the eel question”?

The eel has a very special scientific history. And it's been such a big issue in natural science that the term “the eel question” refers to an especially hard mystery to solve. But the eel question has been different things over the years. From the beginning, it was, What is the eel? Is it a fish or something else? And then it had a lot to do with its sexuality. Does it have sexual differences? Are there males and females?

For centuries, no one could actually find any sexual organs. They couldn't tell whether there were male and female eels.

Because no human being has ever seen eels breed, so to explain how they do it was an extremely hard question.

To this day, no person has ever seen eels mate?

No one has ever seen it because all eels breed in the Sargasso Sea, a region in the Atlantic Ocean, and only there. Aristotle studied the eel and tried to explain how they breed. But when he dissected them he couldn't find any sexual organs. And he came to the conclusion that eels don't breed at all. He thought that the eel just came to life out of nothing, from the mud in the rivers and the seas. Carl Linnaeus came to the same conclusion as Aristotle—that they don't breed and that there are no sexual differences between males and females. But there's an explanation for that. Eels don't develop their sexual organs until they are on the way back to the Sargasso Sea in just the last year of their life.





EYES OF THE EEL Patrik Svensson (left) has been fascinated by eels since he was a child in Sweden. There's a famous eel story in Sweden, he says. "A boy caught an eel in the 1850s and put it in a well. A couple of years ago, a TV crew went to the well and found the eel. It was bleak and small, but had enormous eyes. If the story is true, it has lived for over 150 years in complete darkness."

So every eel we might see in a river or pond in America or Europe has come from the Sargasso Sea?

Exactly. The American eel and the European eel are two different species, but they are very much alike. And both of them only breed in the Sargasso Sea.

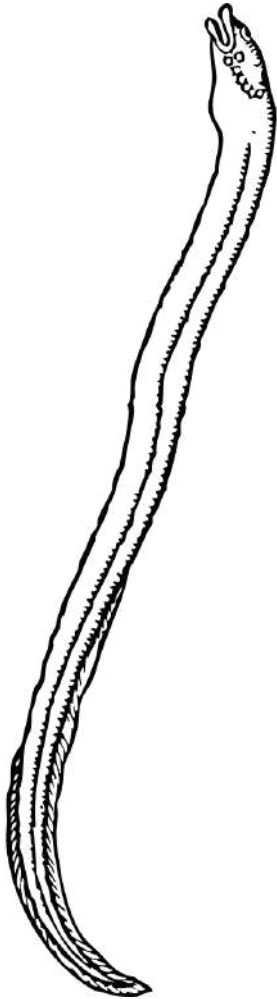
Later, the young Sigmund Freud spent a summer trying to crack the eel mystery. Wasn't he hunting for some evidence of testicles?

Yes, that's an amazing story. Freud was 19 years old, studying natural science, and he wanted to solve the eel question. This was in the 1870s. By this time, they had found a female eel with eggs inside. So to solve the eel question, they had to find a male eel with sexual organs. Freud went to Trieste to find the eel testicle. That was like the holy grail of natural science at the time. He spent a month in Trieste and dissected over 400 eels.

He got the eels from fishermen?

Yeah, every morning he went down to the harbor and picked up a big basket of freshly caught eels. And then he went to his lab and cut them open for the whole day looking for the eel testicle. Of course, he didn't find one testicle. And he had to write a report that concluded that he hasn't been able to solve the eel question. I think it's very funny to think about. This is the man who laid the basis for modern psychological therapy and the man who developed the theories about penis envy and castration anxiety. He started his scientific career by trying to explain the sexuality of a fish. And he failed.

At one point, instead of eating, eels develop sexual organs.



Eventually, people discovered that eels metamorphose into four completely different life stages. What are these different stages?

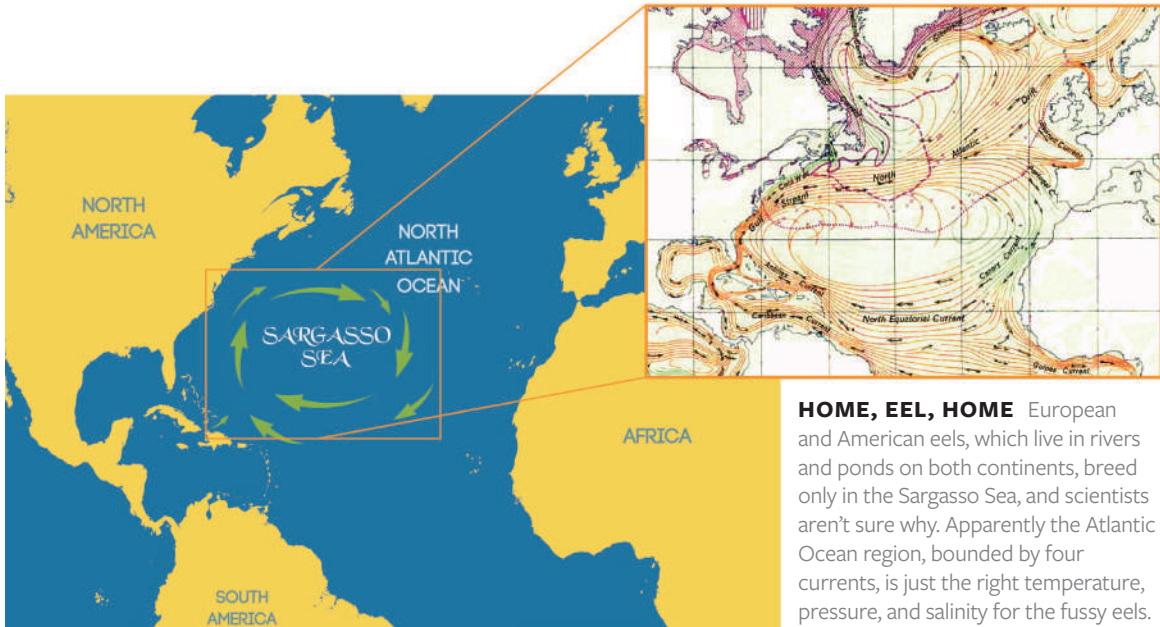
They're born in the Sargasso Sea as a small larva. They have the shape of a willow leaf and drift with the ocean currents. The European eel is east-bound to Europe and the American eel to the west, and when they reach land, they develop into what we call the glass eel. They're the same shape as an eel, but they're totally transparent. Then they find their way up in rivers and seas and streams going into freshwater, and they go through another metamorphosis. They become what we call the yellow eel. And then they live for a very long time as yellow eels in freshwater.

Are yellow eels the ones we eat?

Mostly. Eels can live for a very long time, up to 85 years that we know for sure. But usually when they are 15 to 30 years old, they suddenly leave the freshwater and swim out in the ocean again and return to the Sargasso Sea. When they do this, they transform again and become what we call the silver eel. And this is a very strange creature. They stop eating completely for the whole trip back to the Sargasso Sea, which can take over a year. Instead of eating, they develop their sexual organs. Their eyes change, the way they swim changes. Their final goal is to return home to the place where they came from. And many people also like to eat this silver eel if they catch it in the ocean.

I'm still trying to wrap my head around how time factors into the life cycle of the eel. They might live in a pond for 50 years, and then they suddenly decide it's time to swim back to the Sargasso Sea to reproduce. This is a very fluid sense of time.

It's almost like time and aging are irrelevant for the eel. You know, if the eel can't travel back to the Sargasso Sea, it never goes through the last metamorphosis. It doesn't become sexually mature, and it seems like it can live almost forever in that stage. It's like the eel can put a stop to its own aging. Some eels travel back to the Sargasso Sea after just five, six or seven years, and some eels travel back to the Sargasso Sea when they are 60 years old.



HOME, EEL, HOME European and American eels, which live in rivers and ponds on both continents, breed only in the Sargasso Sea, and scientists aren't sure why. Apparently the Atlantic Ocean region, bounded by four currents, is just the right temperature, pressure, and salinity for the fussy eels.

No human being has ever seen eels breed.

How do they know where to go—both as larvae and also as silver eels? In their first stage, they have to drift across the ocean. And somehow the European eel larvae go in one direction, while the American larvae go in a different direction.

That's still one of the mysteries. Once they're born, the European eel larvae just drift with the Gulf Stream to Europe. This can take two to three years. In the beginning, the American eel larvae are also drifting with the Gulf Stream, but then suddenly they leave the Gulf Stream and head west. How do they know where they are going? The scientific explanation is that there are some genetic differences and the American eel grows faster. So it becomes bigger and stronger earlier, which means that it can leave the current and head to the American continent. But it's the way back, when the silver eel is crossing the Atlantic from Europe to the Sargasso Sea, we still don't really know how they find their way back. We know they use their smell. They have an excellent sense of smell. And probably they also use the electromagnetic fields the same way birds do. But it's a very long and difficult journey.

It's almost like time and aging are irrelevant for the eel.

What's so special about the Sargasso Sea?

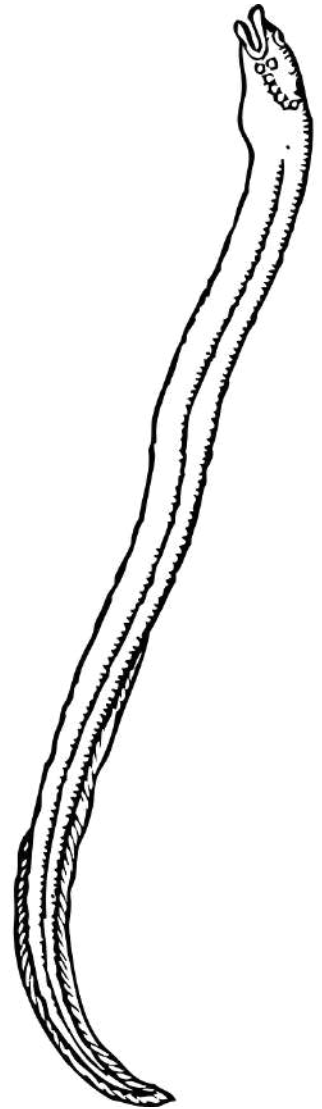
Yeah, why can they only breed there and nowhere else? Probably it has to do with the temperature, with the pressure and with the salinity of the water. But scientists have tried to recreate the exact same conditions in aquariums or big tanks, but still no one has been able to make eels breed anywhere else other than in the Sargasso Sea.

A Danish scientist, Johannes Schmidt, actually cracked the mystery of where eels come from. What did he do?

That's one of my favorite stories in the science history of the eel. This was in the beginning of the 20th century, and by that point, scientists knew there were males and females and the eel was breeding like normal fish. But they still didn't know where it happens. So Johannes Schmidt went out on the ocean with a boat to find the birthplace of the eel. His method was to catch the small larvae and measure them. The place where they were the tiniest, and therefore newly hatched, had to be the birthplace.

Of course, the problem is that this eel larva is very, very small and the Atlantic Ocean is very, very big. So first he sailed from 1904 to 1911 around the shores of Europe and caught a lot of larvae, but they were quite big. So he had to go farther out into the ocean, and he found out that the farther west he went, they actually became smaller. But World War I broke out, so it was very dangerous to sail around the Atlantic Ocean looking for eel larvae, but he just kept on going. He actually sailed around the Atlantic for 18 years before he found the larvae that must have been newly hatched. So he could say that this place, the Sargasso Sea, was where the eel breeds.

This says something about the human urge to understand nature. What makes a man sail around the Atlantic Ocean for 18 years just to know where the eel is born? There wasn't any prestige in it. There was no money in it. It was just curiosity. He had to find out. And that's what makes this scientific history so fascinating. It's actually more a story about humans. ☺



STEVE PAULSON is the executive producer of Wisconsin Public Radio's nationally syndicated show *To the Best of Our Knowledge*. He's the author of *Atoms and Eden: Conversations on Religion and Science*.



Are You Yoda or DARTH Vader?

How to recognize your light and dark sides

BY BRIAN GALLAGHER



YOU MIGHT THINK that to become a better person, you should squelch your inner demons, suppress your darker impulses. That's not quite right, according to Columbia University psychologist Scott Barry Kaufman. The Notorious S.B.K., as some like to call him on Twitter, has a jovial, earnest presence. He's open and curious about others' views on a number of things, mostly on topics touching his areas of expertise—intelligence, creativity, and human personality. He can be firm in his convictions while making a counter-argument gently. He doesn't avoid the social media platform's vitriol but defuses and transcends it. On The Psychology Podcast, he thoughtfully interviews scientists studying the nature of the mind and how to improve people's lives to realize their potential. He's trying to bring back the idea of a "humanistic" psychologist. It's how he identifies himself. This is someone who, he said, seeks to "understand what it means to be a fully vital human who is experientially alive and trying to deal with the paradoxes of human existence."

One of those paradoxes is the way we should relate to the dark side. Recently, Kaufman tweeted, “Integrate your dark side; it may be your greatest creative power when harmonious with the rest of you.” In his new book, *Transcend: The New Science of Self-Actualization*, Kaufman movingly explains the spiritual and intellectual debt he owes to Abraham Maslow, the American psychologist widely known for the idea that to live a psychologically rich life, humans must satisfy a “hierarchy of needs” like survival, social connection, and self-esteem. Kaufman dedicated *Transcend* to Maslow (“a dear friend I’ve never met”), bringing his mentor’s views up to date. “To me,” Kaufman said, “Maslow represents a human who was deeply wrestling with issues that I feel like I’m wrestling with, trying to understand how we can integrate ourselves and become fully actualized human beings without ignoring the dark side.”¹

In two recent papers, published in 2019² and in 2020,³ Kaufman contrasted our light and dark sides, “two very different profiles of human nature,” and argued that we must get in touch with our dark side and harness it, to become whole. Our more aggressive, manipulative, narcissistic propensities aren’t to be cast aside. “Perhaps it would be wise to adopt a dialectical mindset and accept our dark and light sides, being aware of the functions of these traits and the contexts in which they are expressed, rather than ignoring such tendencies within ourselves and in others,” Kaufman and his colleagues concluded in the 2020 paper. “Social trust and affiliation with others, and a relatively lower expression of an antagonistic and exploitative orientation, appears to be a particularly productive path to personality development, life satisfaction, and a deeper connection with humanity.”

If this all sounds very *Star Wars*-y, that’s no mistake. Kaufman takes the moral perspective of *Star Wars* seriously. “Oh, God, I’m obsessed,” Kaufman said. “I’m the first one to scientifically operationalize the *Star Wars* force and create a test that allows people to actually see where they are placed on it. I believe in it. It’s a brilliant framework. You can feel what force is taking hold of you,” the light or the dark. The Jedi, the main protagonists in *Star Wars*, rely on the light, of course. They’re supposed to seek knowledge and peace, value all life, and be motivated by compassion. Their antagonists, the Sith, rely on the dark. They’re supposed to

On the whole human beings want to be good, but not too good, and not quite all the time.

desire power and conflict, value only their self-interest, and be motivated by aggression. To Kaufman these philosophies are, on the whole, accurate representations of how morally relevant personality traits cluster together.

Kaufman designed a survey, “Light vs. Dark Side of the Force Test,” that scores users on six personality “facets”—three from both the so-called Light and Dark Triads. In the 2019 paper, Kaufman and his colleagues found that a new scale he developed to measure the Light Triad was valid, reliably capturing “a loving and beneficent orientation toward others.” This study involved over 1,500 participants, who he recruited using two separate data collection platforms from four demographically diverse samples. “While the Light Triad contrasts with the callous and manipulative orientation of the Dark Triad,” he wrote, “the Light Triad was not merely the inverse of the Dark Triad.”

Scientists have been studying the Dark Triad for about two decades, since psychologists Delroy Paulhus and Kevin Williams published a paper in 2002 proposing it as a part of human personality.⁴ “Of the offensive yet non-pathological personalities in the literature, three are especially prominent: Machiavellianism, subclinical narcissism, and subclinical psychopathy,” Paulhus and Williams wrote. Machiavellianism is an inclination to strategically exploit and deceive others; narcissism, a sense of entitled self-importance; and psychopathy, a tendency to callousness and cynicism.



TOO DARK SIDE Scott Barry Kaufman (left) believes some people can be so high in dark traits, like Emperor Palpatine from *Star Wars*, that they're morally irredeemable—incapable of caring about anyone but themselves. “My esteemed colleague Julia Shaw would probably disagree with me,” Kaufman said. “She thinks everyone’s redeemable.”

An idea was going around in the field that, really, these are names for a single thing. Paulhus and Williams showed otherwise. “We conclude that the Dark Triad of personalities, as currently measured, are overlapping but distinct constructs,” Kaufman said, “There’s a common thread that runs through all of the Dark Triad traits, and that’s exploitation and the desire for antagonism, viewing the world in a zero-sum way.” Like when Darth Vader, toward the end of *Revenge of the Sith*, dealt his friend and former master Obi-Wan Kenobi an absolute: “If you aren’t with me, then you are my enemy.” Vader’s self-hating yet triumphant view of himself is also on-point. “Dark Triad people have no tolerance for anything, or acceptance. They even hate themselves,” Kaufman said. “We found that. They think they’re the greatest, but they don’t love themselves. They’ll be the first to admit, ‘Yeah, I’m a piece of shit as a person,’ but they don’t value that. You see what I’m saying? They like power.”

The Dark Triad, which is associated with committing the “seven deadly sins,”⁵ appears to have cast a spell on researchers. The number of studies on it since Paulhus and Williams’ paper came out has gone up each year, almost exponentially. “People are obsessed with the dark side and it’s interesting questioning why,” Kaufman said. “You go on Netflix and the most highly watched shows are the ones that are unsolved mysteries, or this serial-killer profile. People’s fascination with this stuff is they want to see: How close am I to that person?”

Kaufman developed the Light Triad Scale to bring balance to the force, so to speak. He was motivated by the question, “What would an everyday loving and beneficent orientation toward others look like that is in direct contrast to the everyday antagonistic orientation of those scoring high on dark traits?”

To find this direct contrast, he couldn't merely "reverse code items on the Dark Triad Scale, because that would be a boring scale," Kaufman said; for example, "I like to exploit others/I don't like to exploit others." Instead, he said, "Is there something that is the absence of darkness? Light? I would say no. Light is something more than just the absence of darkness. That's what our research bears out."

He came up with faith in humanity (believing in the fundamental goodness of humans), humanism (valuing the dignity and worth of each human being), and Kantianism (treating people as ends in themselves, not means to an end). "Kantianism," Kaufman explained in his paper, "provided a sensible (and somewhat tongue-in-cheek) contrast to 'Machiavellianism' within the Dark Triad framework." Immanuel Kant and Niccolò Machiavelli are, of course, renowned moral and political philosophers who, in Kant's case, emphasized the ethical strictures of duty and, in Machiavelli's case, made a virtue of being conniving and clever.

Kaufman found no straightforward inverse relationship between Light and Dark Triad traits, which leaves room for people to have a mix of both. "There's a sort of a benevolent orientation that goes through all three of those Light Triad traits, just like the antagonistic orientation that goes through the Dark Triad," Kaufman said. "It doesn't necessarily mean that those who score very high in the Light Triad are delusional. They may recognize and accept, even love, the foibles of human nature."

In his 2020 paper, Kaufman and his colleagues wanted to see how Light and Dark Triad personality profiles are spread out across the human population. "There are those who are extremely high Dark Triad and very, very low Light Triad," he said. "There are those, which are the largest profile of humans, who have a mix. And then there are those who are up the kazoo in Light Triad and very low in Dark Triad."

Kaufman and his colleagues were able to show that females were lower in the Dark Triad and higher in the Light Triad, and that people high in the Light Triad tended to be older, "consistent with the idea that personality is a maturational process." They also found, by analyzing speeches from Senate floor proceedings coded for virtue and vice signals,⁶ that United States senators were higher in the Dark Triad than the

general population—which makes sense, given how competitive politics can be. The senators relatively higher in the Dark Triad also had longer political tenures but co-sponsored fewer bills. "I wasn't surprised," Kaufman said.

He was surprised to find that people are, on average, moderately tipped toward the light. (Maslow, Kaufman said, believed people were basically neutral.) "I think people are basically good when their defenses aren't activated," Kaufman said. "There are people that can bring out the worst in you and environments that can bring out the best in you. We're quick to activate our defenses and there's a million triggers. I wrote a tweet about that: 'I have found that as long as people don't feel that you are attacking their politics, religion, core values, core identity, personal truth, morality, likability, intelligence, talent, creativity, or favorite Pokemon character, people actually tend to be quite polite and kind.' I can be a cheeky psychologist."

Our often unruly environments mean we're not entirely ruled by the sort of traits we have. "It doesn't mean that you're always one way or the other," Kaufman said. "That's not what a trait is. Traits are density distributions. Throughout the course of your day you'll tend to be four or five out of a five-scale on average, but it doesn't mean you don't rack up ones and twos and threes. The Darth Vader density distribution is so highly packed on the four- or five-level of darkness, but it doesn't mean that he can't every now and then have these moments where things slip through, and he saves his son's life, who he cares about."

Kaufman went on, "If there's slivers of love that can slip through the cracks of our hate, it can profoundly change our mindset in the world. I do believe that mindsets are malleable. It's just entirely possible that Darth Vader had a radical mindset shift by the feeling of love being able to slip through the heavy armor of darkness that he has held up as a defense mechanism. That defense mechanism may have served its purpose for many years, but he may have realized that it no longer serves him, or the world. Any one of us at any moment can have that realization."

Perhaps equally crucial is the realization that our dark side is not something we should seek to extinguish. "Harnessing your dark side is essential to becoming a whole person," Kaufman said. "People

Yoda had some dark side. That's why I think Yoda was so wise.

trying to feel more whole will maybe try to cut out all their naughty bits. They'll put on the porn blocker. You know! That's it. 'Now I'll feel whole if I have the porn blocker on. Or I'll cut out all carbs and then I'll feel whole. Or I'll just completely eradicate the dark side and then I'll feel whole.' They still don't feel whole and they're like, 'Why don't I feel whole? I eradicated the dark side.' Well, that's a very naïve view. What I try to really help people with in my book is to help them realize that acceptance is what leads to wholeness."

Complete suppression never works. "The truth will always find a way of popping back, sometimes in full force," Kaufman said. "Whether we're talking about truths within you that you don't want to accept about yourself or truths in the world. There's some people who want to cancel anything, any truth that they don't want to recognize as true. 'Let's just not talk about it. Let's cancel anyone who says anything like it.' You see that analogy there? That's not the best way for a society to become whole and that's not the best way for a human individual to become whole, either." Kaufman believes that the dark side played an important role in motivating people to join the civil rights movement, to fight for social justice. "Sometimes channeling your aggression for real injustices in the world, and integrating that into your higher-level goal, is important. I'm all about integration, baby!"

In *Transcend*, Kaufman offers "growth challenges," some of which focus on helping you to integrate your dark side. "Consider in what ways you have coped with the negative emotions, emotional scars, or negative parts of your identity," he writes. "In what new ways might you be able to take the negative emotions or scars and do something productive with them, such as making small personal improvements or connecting with others, rather than judging yourself?"

Inspired, I took Kaufman's test. When I finished, a picture of Yoda appeared. I am, the analysis informed me, "moderately tipped toward the light side of the force!" Phew. My psychopath rating was less than 10 percent, 26 percent below the average; the average Machiavellianism score is just below 40 percent, and mine came in at 5 percent lower than that. But it turns out I'm a bit of a narcissist. I scored 19 percent higher than the average of 40 percent. Instinctively I attribute this to my identity as a writer. George Orwell, in his 1946 essay "Why I Write," listed "sheer egoism"—"the desire to seem clever, to be talked about, to be remembered after death"—among his four "great motivations" for writing, the others being "aesthetic enthusiasm," "historical impulse," and "political purpose." About egoism, Orwell wrote, "Writers share this characteristic with scientists, artists, politicians, lawyers, soldiers, successful business men—in short, with the whole top crust of humanity."

Star Wars philosophies are, on the whole, accurate representations of how morally relevant personality traits cluster together.

I'm OK with that. In another essay (which Kaufman quotes), Orwell writes, "On the whole human beings want to be good, but not too good, and not quite all the time." I scored just a percent higher than the average faith-in-humanity score—60 percent. But my humanism is extreme. The average score is around 70 percent and mine was above 90 percent. And, at just above 80 percent for Kantianism, I'm 6 percent higher than the average. So, overall, not *that* high-scoring in the Light Triad. At least compared to Kaufman, who scores high. He said, "Surprised you're not higher in humanism." I took it as a compliment.

Before I bid Kaufman farewell, I asked him how Yoda, a Jedi paragon, would take his advice about integrating the dark side. Wasn't Yoda pure light?

"Yoda had some dark side," Kaufman said. "That's why I think Yoda was so wise. Yoda had the ability to feel the dark side. Yoda's strength actually was more of his ability to control and channel it, rather than not have any idea what it feels like. I heard Jordan Peterson, [a Canadian psychologist], say something like this once—that to be able to have the dark side within you and have the capacity to control it makes you much more powerful than to not have access to that state at all. I've been thinking along similar lines. I'm a big fan of meditation for that reason, where you just nonjudgmentally check in with yourself throughout the day and be like, 'Oh wow, I'm feeling the dark side right now.' Meditate on it with love." ☯

BRIAN GALLAGHER is an associate editor at *Nautilus*. Follow him on Twitter @bsgallagher

To explore your own dark and light sides, take Kaufman's psychological survey, "Light vs. Dark Side of the Force Test," at <https://scottbarrykaufman.com/lighttriadscale/>.

REFERENCES

1. Muris, P., Merckelbach, H., Otgaar, H., & Meijer, E. The malevolent side of human nature: A meta-analysis and critical review of the literature on the dark triad (Narcissism, Machiavellianism, and psychopathy). *Perspectives on Psychological Science* **12**, 183–204 (2017).
2. Kaufman, S.B., Yaden, D.B., Hyde, E., & Tsukayama, E. The light vs. dark triad of personality: Contrasting two very different profiles of human nature. *Frontiers in Psychology* **10** (2019).
3. Neumann, C.S., *et al.* Light and dark trait subtypes of human personality—A multi-study person-centered approach. *Personality and Individual Differences* **164**, 110121 (2020).
4. Paulhus, D.L. & Williams, K.M. The dark triad of personality: Narcissism, Machiavellianism, and psychopathy. *Journal of Research in Personality* **36**, 556–563 (2002).
5. Jonason, P.K., Zeigler-Hill, V., & Okan, C. Good v. evil: Predicting sinning with dark personality traits and moral foundations. *Personality and Individual Differences* **104**, 180–185 (2017).
6. ten Brinke, L., Liu, C.C., Keltner, D., & Srivastava, S.B. Virtues, vices, and political influence in the U.S. Senate. *Psychological Science* **27** (2015).

Gender Is What You Make of It

*Margaret Mead, Ruth Benedict, and the
relationship that changed social science*

BY CHARLES KING



KRISSIKUNTERBUNT / SHUTTERSTOCK

IN JULY 1925, MARGARET MEAD, a doctoral student at Columbia University, set off on a cross-country train journey with a young faculty member, Ruth Benedict.

Mead was bound for the West Coast and then American Samoa, her first fieldwork expedition as a junior anthropologist. Benedict was stopping in New Mexico to study myth and ritual in the Zuni Pueblo. The journey took them through Ohio to Illinois, across the prairie, then south toward the deserts. It was the longest the two of them had ever spent together, certainly the longest without their husbands in tow.

They had become acquainted more than two years earlier, Mead as an undergraduate at Barnard College, Benedict as her teaching assistant. It had taken time for Mead to stop referring to “Mrs. Benedict,” but over the years, something had changed. “She rests me like a padded chair and a fireplace,” Benedict jotted in her diary. Now, on the train west, Mead would remember weeping in Benedict’s arms, parsing her troubled marriage and other romantic entanglements. Benedict would later lie awake thinking of the nights they spent on the train—making love, kissing Mead’s fingers, trailing her lips across the palm of her hand. “*Tofa*, my sweetheart,” Mead wrote in a letter once she got to Samoa, using the local term for goodbye. “In my dreams I bury my face in your hair.” She had long signed her notes to Benedict with “love,” as one might to an older sister. But now she could say it all plainly, outright. “And always I love you.”

How could Mead make sense of a way of being and loving that, in her own society, was cloaked in angst and secrecy?

For the rest of their lives together, they would be each other's polestar, sharing insights and triumphs, frustrations from the field, gossip from the Columbia anthropology department, confidences about their marriages to men and their romances with other women, and critiques of whatever manuscript the other one happened to be working on at the time. "For the first time in my life, I expect defeat," Mead told Benedict not long after they parted near Gallup, New Mexico. But within a few years, she was on her way to becoming one of the most celebrated and controversial public scientists of the century. The book she completed after that trip, *Coming of Age in Samoa*, published in 1928, would be hailed as a classic in the literature on sexuality and adolescence. Benedict's star was slower to rise but no less brilliant. Her *Patterns of Culture*, published in 1934, and *The Chrysanthemum and the Sword*, an empathetic analysis of Japanese society published right after World War II, remain signposts in the history of the social sciences.

FOR MEAD AND BENEDICT, social theory was a tool for making sense of the world, but it could also be a lever against your own predicaments. To do anthropology well, you had to alienate yourself from everything familiar, to take a slow train toward another way of seeing reality. The payoff was a liberating and original way of viewing your own society, denuded of its specialness and its constraints. And if you had always felt somehow out of kilter in your own culture—an "abnormal" or a "deviant," an "invert" or a "mixed type," as Benedict would later put it in her writings—you might come to understand why your own life had been such a struggle.

"I believe every person of ordinary sex endowment has a capacity for diffuse 'homosexual' sex expression," Mead wrote to Benedict in 1933, this time from a new field site in New Guinea. "To call men who prefer [a] different expression 'feminine' or women ... 'masculine,' or both 'mixed types' is a lot of obfuscation." Everything was to some degree potentiality, until it got channeled in a specific direction by circumstance and the rule-scape into which one was born. Mead had seen all of this at work among people she met in the field—the "deviants" who lived perfectly satisfactory lives when a given society made room for them—and she could see it in herself, in the hidden yearnings and desires she shared with Benedict. She was now pursuing a new line of thought that would be "the climax of the work I've done this last year," she told Benedict, "a combination of anthropology and reviewed biography."

What if a key to understanding human difference lay in how societies standardized an individual's specific personality? All this was easiest to see, Mead said, when it came to women and men. In her fieldwork in New Guinea and elsewhere, she had recorded men who dressed as women, women who took on the social role of men, and everything in between. But describing things that way felt like a conceptual straitjacket. She found herself forced to explain an entirely different social world by relying only on the binary categories of female and male that she knew from her own society.

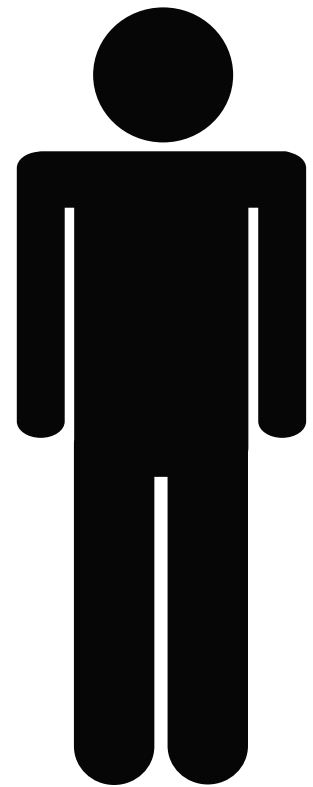
The world Mead knew best—the United States in the interwar years—had selected a thing it called sex to be the container in which an individual’s essential self resided. Biological women and men were said to have basic qualities that everyone in the culture could describe fluently. Boldness, aggressiveness, and dominance got catalogued as male. Gentleness, motherliness, and creativity got catalogued as female. But no one in Mead’s society associated being big-eared or green-eyed with inherent traits of character. Claiming that people with protruding ears were naturally weak-willed, for example, would seem plain silly. Her culture had evolved in such a way that being female or male was a basic, binary, and deeply meaningful way of classifying reality. Having prominent ears or green eyes wasn’t.

By 1935 she had wrapped these thoughts into a new book she called *Sex and Temperament*. It represented Mead’s most serious attempt to bring fieldwork together with grand social theory, and then to aim all of it at the core problem that ran through her long relationship with Benedict: how to make sense of a way of being and loving that, in her own society, was cloaked in angst and secrecy.

Our society makes a heavy investment in sex differences, Mead wrote. It expects women and men to behave very differently, from birth forward, simply on the basis of their biology. It “plays out the whole drama of courtship, marriage, and parenthood in terms of types of behavior believed to be innate and therefore appropriate for one sex or for the other.” We build our slang, our jokes, our medicine, even our obscenity around the belief that sex and social behavior go together. A person who doesn’t fit their designated type—someone who gets labeled an effete man or a manly woman—seems at odds with the natural order of things. Mead knew what that felt like. “You keep [your mind] too near your devices for loving,” one male colleague told her, drawing the link explicitly. “Loathsome bitch,” said another.

All societies seemed to assign specific social roles to these biological types. But not all human cultures believed that these social roles were *derived* from biology, Mead observed, or that differences between women and men were categorical and obvious. For one thing, you needed a modern science of biology to do that—something that a traditional society in Samoa or New Guinea didn’t really have. Even then, if you could demonstrate that, on average, people with penises were disposed to behave one way and those without to behave another, you were still left with two problems. First, the degree of difference within each category was likely to be greater than between the categories. No great gulf of behavior separated *all* men from *all* women. Second, there was no easy way of distinguishing the behaviors that were a product of social factors from those that were supposedly innate. Penises couldn’t explain everything.

The only thing that was universal, Mead said, was the independent existence of sexual roles and of differences in individual personalities, or what she called temperament. Where societies differed was in how they drew lines between these two things—in other words, which specific

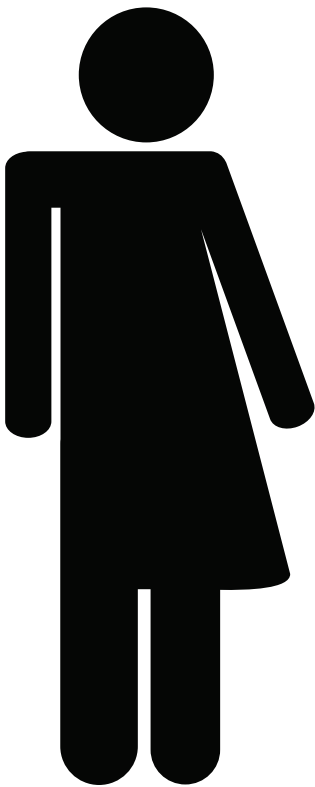


temperaments a society assigned to femaleness and maleness. You couldn't begin to talk about deep differences between the sexes until you also understood the alleged qualities a society attributed to each sex. Indeed, you'd also want to know whether a society bothered much with assigning unique, categorical qualities to them at all. From her research in New Guinea, she had at her fingertips three very different societies that, on her account, just didn't—three peoples living in the Sepik River region that she knew as the Arapesh, the Mundugumor, and the Tchambuli.

All three communities gave discrete tasks to women and men. On her account, the Mundugumor thought fishing was an occupation appropriate mainly to women, while the Arapesh considered painting in color to be the exclusive purview of men. They had their own local theories about why this was a commonsensical arrangement, but no one seemed to believe that these roles had anything to do with inherent personality. Women were better at carrying heavy loads because their heads were harder and stronger, the Arapesh would say, not because women were naturally suited to servile tasks. The Mundugumor valued acquisitiveness and suspicion, according to Mead, but they believed these traits to be equally dispersed among women and men. The Tchambuli tended to put men in the role of artists who spent their days carving wooden masks and dancing, while the women fished and prepared food. But they, too, made no distinction between women and men as to the distribution of their innate potentialities.

WESTERN SOCIETIES, MEAD CONCLUDED, had learned over time to associate specific temperaments with the social roles into which they placed the biological sexes. Since women were by and large given the role of nurturing mother, it was convenient to believe that they were by nature careful, attentive, and focused on the wellbeing of children. Since men were given the roles of politician and war-maker, it was equally convenient to believe that biology predisposed them to discernment and bravery. But to see this alignment of sex and temperament as the only possible way of organizing society was to mistake effect for cause. Sex roles, Mead argued, came first, the product of a long and complex process of circumstance, cultural borrowing, change, and chance. Only later came the “standardization of sex-temperament,” as she called it, to fit these preexisting roles.

The real question to ask of her own society, she said, was how far people might be willing to open themselves to the idea that human potential did not come prepackaged according to biological sex. Following the social science usage of the time, Mead never employed the term gender in anything other than a linguistic sense, such as nouns that might be classed as feminine, masculine, or neuter. But in *Sex and Temperament*, she wanted to draw a bright distinction between sex-as-biology—this brand of genitalia or that array of secondary sexual characteristics—and sex-as-social-category, or what would later come to be called gender. Sex could be thought of as





MARGARET MEAD PAPERS, LIBRARY OF CONGRESS

COMING OF AGE Margaret Mead is pictured here as a student at Barnard College circa 1923, when she met Ruth Benedict. Mead was on her way to becoming one of the most celebrated and controversial public scientists of the century.

Every year seemed to produce another front in the battle against the purveyors of old certainties.

a class of biological facts, at least for all but a small portion of human beings. Gender, on the other hand, was the product of a specific time and place—the discrete social positions that a given society assigned to women and men, or alternatively the menu of roles, behaviors, attractions, and potentialities that it made available to people, with little reference to biological sex at all.

All of this also gave Mead a way of understanding her own fate, as well as Benedict's. Cultures are cunning tailors. They cut garments from convenience and then work hard to refashion individuals to fit them. Real liberation wasn't necessarily about making women more manly or allowing men to be effeminate. It was about unleashing human beings' potential from the roles that society had fashioned, seeing each person as a parcel of possibilities that might get expressed in many creative ways. Cultural change came about when enough people began to see that the old clothes simply didn't fit.

Mead felt that her own society was obsessed with seeing people as "types" of some deeper, innate reality: black or white, female or male, normal or deviant, intelligent or feeble-minded. But there were alternatives. "A civilization might take its cues not from such categories as sex, race or hereditary position in a family line," Mead concluded in *Sex and Temperament*, "but instead of specializing personality along such simple lines recognize, train, and make a place for many and divergent temperamental endowments." To do otherwise wasn't at base a matter of injustice or oppression, although it produced plenty of both. It was just a terrible waste, a vast squandering of talent and energy, all bottled up inside people who were forced to live their lives as tragically less-than. She was making a point that campaigners for women's rights, disabled access, and marriage equality would eventually take as fundamental: that nothing enhances social potential more than removing the barriers to full participation—a glass ceiling, a staircase, a law that delegitimizes the person you love.

In the years after *Sex and Temperament* was published, Mead would marry for a third time. Benedict's husband would die of a heart attack—which also allowed her, as a widow, to move toward a tenured professorship at Columbia, something denied to married women at the time. Benedict herself succumbed to heart trouble several years later, in 1948. Condolences were sent to Mead as if she were the next of kin. In most ways that mattered, she was. "The discovery of anthropology ... proved to be her salvation. That is where you came into the picture, Margaret," wrote Benedict's younger sister in a letter. "One of the deepest satisfactions of her life has been the privilege of stirring up your intellect, and then watching you carry the torch into fields where she could never go."

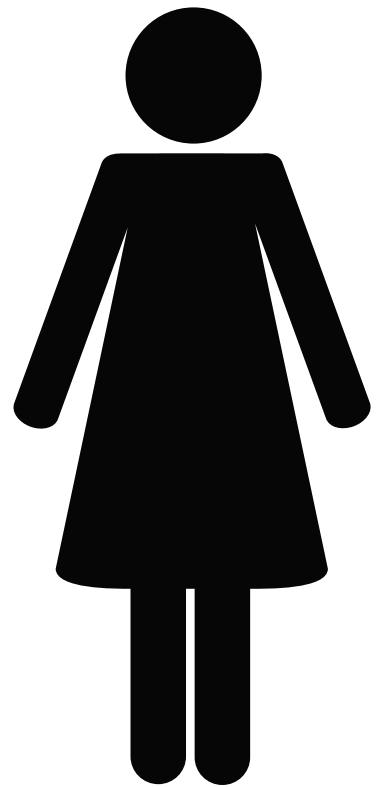
Mead lived for another 30 years. She worked from attic rooms in the American Museum of Natural History in New York, her main employer, in a nest of field notebooks and tagged artifacts, handwritten letters and typed mimeographs, thousands upon thousands of pages and objects. On weekdays she could be seen purposefully striding the hallways with a

notched walking stick, the better to support a weak ankle she had nursed since graduate school, and wearing a distinctive felt cape, an affectation of middle age. Her early books on Samoa and New Guinea each went through as many as 17 editions and 20 foreign translations. Her typical year's output might include a scholarly book, articles in learned journals, encyclopedia entries, and short pieces in *Good Housekeeping* and *Redbook* that spun anthropological findings into practical advice. Mead's address book was a Who's Who of the era's greatest sociologists, philosophers, psychologists, and political leaders. She reveled in the new findings that were upending old ways of thinking. Alfred Kinsey catalogued the enormous variety of sexual practices unspooling inside suburban bedrooms. William H. Masters and Virginia E. Johnson conducted laboratory studies of human erotic response that characterized same-sex attraction not as an abnormality but as a form of sexuality to be understood. Their work would inform the striking, by the late 1980s, of homosexuality from psychologists' lists of diagnosable illnesses.

For Mead's 75th birthday in December 1976, *The New York Times* featured a full-page announcement in her honor. Less than two years later, in the spring of 1978, she was diagnosed with pancreatic cancer. She died that November. In the decades that followed, there would be a U.S. postage stamp with her portrait and a Presidential Medal of Freedom, awarded posthumously for her struggle to show, as the White House citation read, "that varying cultural patterns express an underlying human unity." Her stick and cape were eventually placed on permanent display near the American Museum of Natural History's exhibit on the cultures of the Pacific. When visitors go there today, they enter under a sign welcoming them to Margaret Mead Hall.

IN 1987 PHILOSOPHER ALLAN BLOOM published his treatise on the parlous state of American society and the country's misguided universities. *The Closing of the American Mind* became a bestseller and a classic among cultural conservatives. "Almost every student entering the university believes, or says he believes, that truth is relative," Bloom wrote in the book's first sentence. He went on to name the people who had led young people into this amoral thicket. "Sexual adventurers like Margaret Mead and others who found America too narrow told us that not only must we know other cultures and learn to respect them, but we could also profit from them," he wrote with sarcasm. "We could follow their lead and loosen up, liberating ourselves from the opinion that our taboos are anything other than social constraints. We could go to the bazaar of cultures and find reinforcement for inclinations that are repressed by puritanical guilt feelings."

Although he was surveying the entirety of Western thought, Bloom could think of very few women worth mentioning. Margaret Mead and Ruth Benedict were among them—and the source of the problem, as Bloom saw it. There had been a fundamental transformation in the intellectual outlook of the West, he believed. It involved a turning away from tradition





BEAUTIFUL PALACE

To Margaret Mead, Ruth Benedict was a “beautiful walled palace ... the ineradicable root, the one homosexual thirst there is not getting by.” Benedict, pictured here around 1931, would see her own star rise with her books, *Patterns of Culture* and *The Chrysanthemum and the Sword*.

and an embrace of the wrongheaded idea that there was nothing world-shatteringly special about American democracy or its traditional ways of dealing with gender, sex, and love. The relativity of sexuality, morality, history, and social reality had become the new orthodoxy, scotching the ability of young people to search dispassionately for what constituted an authentic, meaningful life.

Had they been around, Mead and Benedict would have been surprised by the news that they had triumphed. They had lived their lives as struggles. Every year seemed to produce another front in the battle against the purveyors of old certainties, a new frontier on which to show that difference was nothing to be afraid of. Every society must come to grips with the same basic problems, they insisted: how to organize itself, how to raise a child, how to treat the aged, how to reproduce properly, how to love well. Over time humans have developed many answers to these questions. The versions most familiar to some Americans—a spring wedding in white, summer camp for a rambunctious adolescent, a declining parent placed in the care of strangers—don’t necessarily produce happiness, efficiency, or fulfillment. They are just one way of doing things, the product of *this* history, *this* philosophizing, and *this* set of conditions.

Go awkwardly, bravely to places where we are sure to meet someone unlike us—a tropical island, a desert pueblo, or across town.

Our molecules, genes, and brains nudge us in particular directions. Sometimes, they shove us, shaping the possibilities of existence and our individual pathways through life. But what we mean by things like appropriate gender roles, proper sexual behavior, or an abnormal mind is a creation of human beings in repeated interaction with one another—that is, of a society—not of our innards. Distinguishing right from wrong is a matter of philosophy, yet it rests on a matter of fact: our prior conception of what is obvious or given, versus what is ludicrous or absurd. The expansion of our sense of morality depends on first enlarging the realm of the thinkable.

And that in turn often requires, as it did for Mead and Benedict, to go awkwardly, bravely to places where we are sure to meet someone unlike us—a tropical island, a desert pueblo, or across town. All societies are just snippets of “the great arc of potential human purposes and motivations,” Benedict once wrote. The world at large is a laboratory of possible lives. To live intelligently and act justly come down to the same thing, expressed in a scientific finding that these two women spun out of their fieldwork adventures, their second-class status as female academics, their unnamable love: that there is no such thing as a defective human being. ☺

CHARLES KING is the author of *Gods of the Upper Air*. His other books include *Midnight at the Pera Palace* and *Odessa*, winner of a National Jewish Book Award. His essays and articles have appeared in *The New York Times*, *Washington Post*, *Foreign Affairs*, and *New Republic*. He is a professor of international affairs and government at Georgetown University. You can follow him on Twitter at @charleskingdc.

Adapted from *Gods of the Upper Air* by Charles King. Reprinted by permission of Anchor Books, an imprint of the Knopf Doubleday Publishing Group, a division of Penguin Random House LLC. Copyright © 2019 by Charles King.



An Ancient Site with Human Skulls on Display

Where our ancestors began to elevate themselves above nature

BY JO MARCHANT

BAIMIENG / SHUTTERSTOCK



ABOVE OUR HEADS, the lights are going out. Instead of thousands of stars in the heavens, artificial light pollution means that in today's cities we see only a few dozen. A recent global survey found that most people in Europe and the United States can no longer even see our own galaxy, the glittering Milky Way. It's an inexorable erosion of our skies that mirrors our impact on the Earth. At what point did we become entitled masters of the cosmos, using our technological power to dominate our environment? This shift in our nature is sometimes traced to the Industrial Revolution, or further back to the birth of science, or perhaps the invention of farming. Yet our first step was taken even earlier, revealed by an eerie homage to the underworld buried within the foothills of Turkey's Taurus Mountains.



VULTURE STONE This pillar at Göbekli Tepe pictures an anthropomorphic buzzard. The site may be the first place where “humans are no longer depicted as a coequal part of nature, but are clearly more prominent and ‘raised’ above the animal world,” archaeologists have written.

Archaeologists there have been studying a 15-meter-high mound called Göbekli Tepe—“Potbelly Hill.” The area is packed with prehistoric pillars and enclosures, including a layer of large circles, up to 20 meters across, dating to the tenth millennium B.C. Up to 12 T-shaped pillars around the edge of each space were connected by a stone bench. Two more giant pillars—up to 5.5 meters high and each weighing several tons—stood parallel in the center, with traces of carved arms, belts, and loincloths made of animal skins. Other stones are covered in carvings of animals: spiders, scorpions, vultures, foxes, boar, gazelles. It is the earliest great stone monument known and a staggering 6,000 years older than Stonehenge.

In these stones, German archaeologist Jens Notroff and his colleagues, who have worked at Göbekli Tepe since 2014, see clear evidence of our shifting

relationship to the natural world. In the earlier cave art of the Palaeolithic, people are rarely represented; it’s the animals that take center stage. By contrast, the foxes, snakes, and scorpions of Göbekli Tepe are reduced to smaller attributes or decorations on those huge anthropomorphic pillars. As the team put it in 2015, “humans are no longer depicted as a coequal part of nature, but are clearly more prominent and ‘raised’ above the animal world.” The art shows, they argue, that people had already begun exerting power over nature: a “mental control” that led to the subsequent physical control of domestication.

Another striking aspect of Göbekli Tepe is an apparent obsession with death. The art here features multiple images of headless people as well as statues of heads apparently broken from larger statues. Among animal remains found in the sediment—thought to be

A house wasn't just a place to live but the expression of a mythical world. It was a model of their universe.

the debris from lavish feasts—are hundreds of pieces of human bones. Anthropologists reported in 2017 that most of these are from skulls, and that some are carved with grooves and holes in a way that suggests intact skulls were once hung up for display.

Klaus Schmidt, who discovered Göbekli Tepe in 1994, interpreted the abstract T-shaped statues as beings from a “transcendent sphere” (naturalistic statues found at this site and elsewhere show that the builders could depict realistic humans when they wanted to). And, intriguingly, the circular enclosures appear to have been accessed not via doors or gateways but through small openings in “porthole stones.” One of these stones is decorated with a boar lying on its back. The circles, Schmidt suggested, represented the realm of the dead, which could only be entered by crawling through the hole.

In fact, a preoccupation with death and particularly skulls emerges across the region at this time and in the centuries following, with human remains commonly buried inside people's houses. At sites such as Jericho and Ain Ghazal in Jordan, dating to the tenth and ninth millennia B.C., selected skulls were removed after death and given faces made of plaster, with shells for eyes, before being placed under the floor. At Çayönü, in southern Turkey, archaeologists found a building that they called the “House of the Dead,” dating to around 8000 B.C., with 66 skulls beneath the floor and the remains of a further 400 people. It also held a large, flat stone like an altar, with traces of human and animal blood.

A particularly bizarre example is Çatalhöyük, a 20-meter-high mound on Turkey's Konya Plain, a few hundred kilometers from Göbekli Tepe. The mound contains mud-brick houses from a settlement that housed thousands of people at its height around 7000 B.C. The closely packed houses were dug down into the ground, and entered by climbing down a ladder through

a hatch in the roof. Inside, the houses were richly decorated with paintings, as well as sculptures of animals that burst out of the walls. There were no doors; to move between rooms, inhabitants had to crawl through portholes. The small chambers were further subdivided into sections, just a meter square, which occupied different vertical levels, with their edges marked or guarded by bulls' heads. Human bones were found buried beneath these platforms and in the walls, including a stillborn fetus enclosed in a brick.

The residents seem to have found the walls of their houses highly significant. As well as embedding objects in them, some had small, undecorated alcoves just big enough for a single person to crouch within. And wall sculptures of animals such as leopards and bulls were repeatedly replastered, up to a hundred times.

It seems a crazy way to live: cramped, dark, and difficult to move around. Ian Hodder, an archaeologist at Stanford University who has been excavating the site since 1993, has concluded that for the residents of Çatalhöyük, the physical structure of their houses was entwined with their mythical beliefs: “The world was replete with substances that flowed and transformed, and with surfaces that could be passed through.”

Archaeologist and rock-art expert David Lewis-Williams goes further. He believes that people here were deliberately mimicking the experience of crawling through limestone caves. There are such caves in the Taurus Mountains, just a couple of days' journey to the south, and pieces of stalactite and limestones from these caves have been found in the Çatalhöyük houses. Lewis-Williams has suggested that—just like visitors to the caves of Upper Palaeolithic western Europe—the people who built these houses saw the walls as permeable interfaces, or portals to the cosmos's spirit realms. At Çatalhöyük a house wasn't just a place to live but the material expression of a mythical world. It was a model of their universe.



Human bones were found buried beneath the platforms, including a stillborn fetus enclosed in a brick.

Houses modeled on the cosmos are still known in societies around the world. The Barasana people in the dense forests of Colombia, for example, traditionally live in wooden longhouses called *malokas*. Each one is a miniature universe in which the roof is the sky and a vertical post, called “the seat of the sun,” aligns with the sun’s rays every day at noon. The major horizontal roof beam, oriented east-west, is called “the sun’s path.” The floor is the Earth and beneath it is the underworld, where the dead are buried. In his 2005 book, *Inside the Neolithic Mind*, Lewis-Williams argues that a similar principle might explain other Neolithic monuments and cult buildings found in the Near East, such as the stone circles of Göbekli Tepe. Like Schmidt, he concludes that they modeled the spirit world, or the cosmic realm of the dead, incorporated spaces that are sunk into the ground, with human remains often under the floor.

Were the builders only concerned with the underworld, or did they also look up at the sky? Göbekli Tepe is located on a high point in the landscape, so would have offered a panoramic view of the heavens. Some researchers have suggested that the flat tops of its pillars could have been used to observe the rising or setting of prominent stars, such as Orion’s Belt, or were built to commemorate the gradual appearance in the sky (due to precession) of the bright star Sirius. Others have linked the animal carvings at the site to specific constellations, proposing that a scorpion depicted underground might represent Scorpio below the horizon.

Notroff isn’t convinced: He suspects the enclosures were at least partly subterranean, dug down into the sediment, and had roofs, perhaps made from an organic material such as animal hides. So the site may make more sense as a terrifying journey to a cave-like underworld than as an astronomical observatory. He has experienced these spaces beneath a roof recently built to protect the site, and the shadows make the pillars and carvings look larger and “even more awe-inspiring,” he told me. “I can only imagine how all these images of giant scorpions, curling snakes, and snarling predators must have affected the young hunter on his first descent into the darkness, maybe with nothing but the flickering light of a torch.”

This doesn’t mean that the builders of Göbekli Tepe weren’t interested in the sky. One of the best-preserved



COSMIC REALM Archaeologists say that Göbekli Tepe (left), unearthed in Turkey, may be modeled on the spirit world, the cosmic realm of the dead, with incorporated spaces that are sunk into the ground, and human remains under the floor.

pillar statues wears a carved necklace decorated with a disc and crescent. These symbols are thought to refer to the moon; it has even been suggested that the necklace identifies this pillar as a moon-deity. Either way, structures like Göbekli Tepe reveal a fundamental shift in how people related to the cosmos. It seems likely that the people who constructed these sites had a similar tiered universe—with lower, middle, and upper worlds—to their predecessors in the Palaeolithic and traditional hunter-gather societies today. Lewis-Williams argues that altered states of consciousness were likely still important as a way of journeying between these different cosmic realms.

It's significant that such journeys now occurred in man-made rather than natural settings. The residents of Çatalhöyük appear to have copied the cramped passages of natural caves. Elsewhere, the greater control that people now had over these portals allowed the development of simpler, more formulaic designs: circles, pillars, squares. As Lewis-Williams has pointed out, this shift toward purpose-built structures would have allowed for greater social control, with the emergence of powerful elites and formal rituals—decorating and displaying selected skulls after death and possibly human sacrifice—that prescribed who could access these other realms and how.

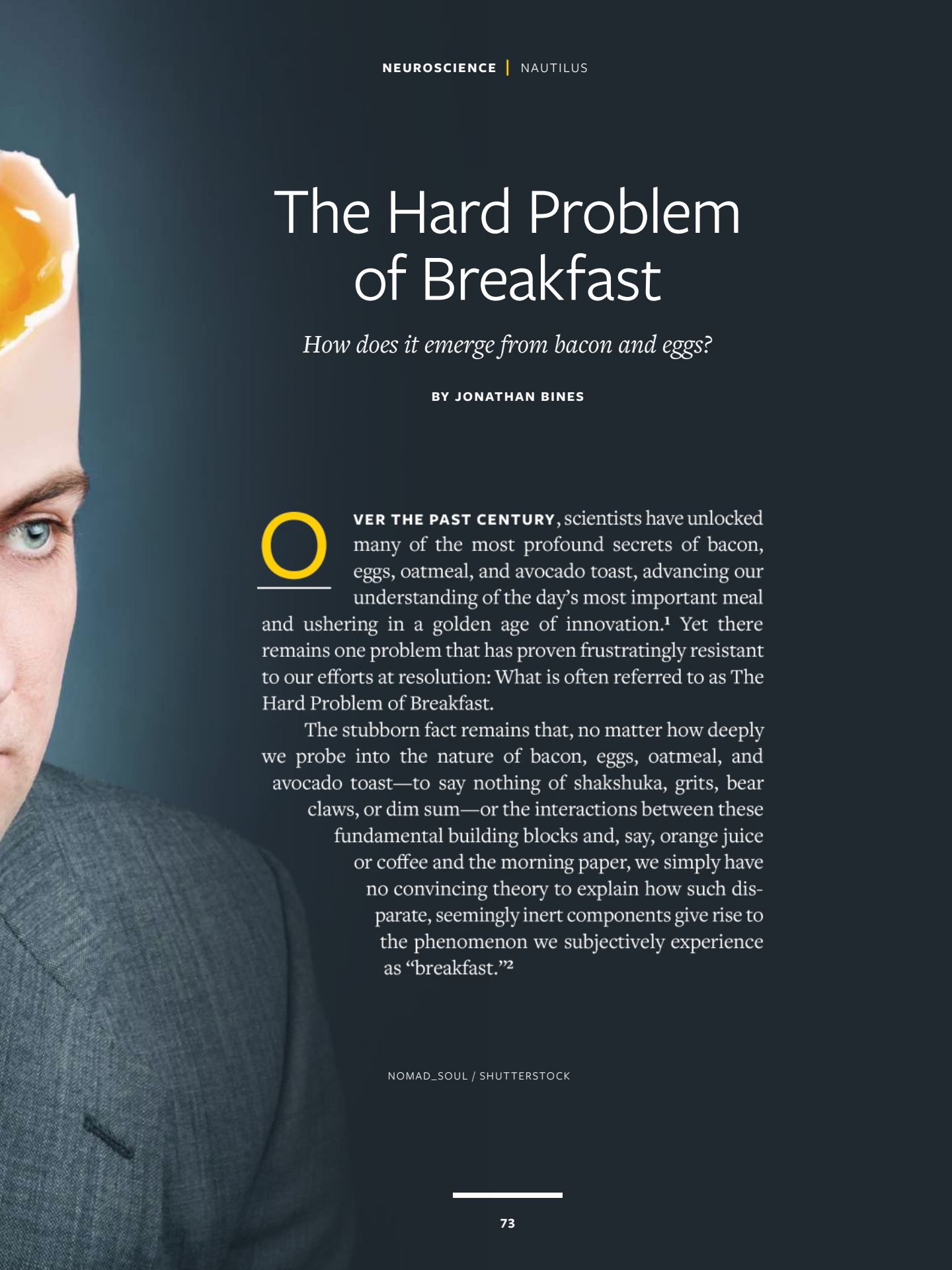
Göbekli Tepe epitomizes two important changes that seem to have happened in parallel around 12,000

years ago, both of which involve societies beginning to separate themselves from, and elevate themselves above, nature. The spirit realms became populated primarily not with animal guides but human ancestors. Instead of using existing caves or natural features as entrances to other worlds, people started to build their own. ☺

JO MARCHANT, an award-winning science journalist, is the author of *The Human Cosmos*. Her previous book, *Cure*, hit the *New York Times* best-seller hardcover nonfiction and science lists. She is also the author of *Decoding the Heavens*, which was, like *Cure*, short-listed for the Royal Society Prize for Science Books.

Adapted from *The Human Cosmos: Civilization and the Stars* by Jo Marchant, published by Dutton, an imprint of The Penguin Group, a division of Penguin Random House, LLC. Copyright © 2020 by Jo Marchant.





The Hard Problem of Breakfast

How does it emerge from bacon and eggs?

BY JONATHAN BINES



OVER THE PAST CENTURY, scientists have unlocked many of the most profound secrets of bacon, eggs, oatmeal, and avocado toast, advancing our understanding of the day's most important meal and ushering in a golden age of innovation.¹ Yet there remains one problem that has proven frustratingly resistant to our efforts at resolution: What is often referred to as The Hard Problem of Breakfast.

The stubborn fact remains that, no matter how deeply we probe into the nature of bacon, eggs, oatmeal, and avocado toast—to say nothing of shakshuka, grits, bear claws, or dim sum—or the interactions between these fundamental building blocks and, say, orange juice or coffee and the morning paper, we simply have no convincing theory to explain how such disparate, seemingly inert components give rise to the phenomenon we subjectively experience as “breakfast.”²

NOMAD_SOUL / SHUTTERSTOCK

Scientists still waffle on the origins of breakfast.

It has long been understood that no breakfast can exist in the absence of its constituent foods and their related supporting structures such as plates and bowls, utensils, and toasters.³ A breakfast must self-evidently be “of” something to be considered a breakfast at all. Yet despite technological advances that have enabled scientists to probe these components at the most minute levels, we have to date found no trace of the theorized Breakfast Particle or any other plausible mechanism by which breakfast could emerge from the underlying biochemical or nutriophysical activity.⁴

In particular, we know from the work of Scherzinger, *et al.* that breakfast is not located in the eggs.⁵ Although eggs are highly correlated with the emergence of breakfast, Scherzinger and his team at the Boston Institute for Alimentary Investigation were able to show definitively that breakfast cannot be located within any part of the egg—white or yolk—and that this result remains consistent regardless of the method of preparation—soft or hard boiled, over easy, scrambled, Benedict, etc. Moreover, these results hold true even when the egg is

highly distributed throughout the dish, as in quiche.⁶ Morris and Shrenk have gone even further, demonstrating that breakfast may emerge even in the complete absence of eggs—such as during oatmeal with walnuts and brown sugar.⁷

As it has become increasingly clear that breakfast’s secret will not be discovered among the large-scale tofu scrambles and sausage McMuffins of our ordinary experience, scientists have turned their attention to the smallest scale: its fundamentally quantum nature. Where Newton once conceived of a fixed breakfast (an apple, say) occupying a definite location in space and time, today we must consider our morning meal not as an objective fact, but rather as a kind of cloud of comestible potentiality—a statistical superposition of all possible breakfasts that mysteriously “collapses” into bacon and eggs or an everything bagel only upon the “order” of a “diner.” But how this collapse occurs, and the exact nature of this proposed “diner,” remain frustratingly opaque.⁸

Studying the particles of a complete breakfast has allowed us to calculate certain probabilities with great accuracy (for example, the likelihood of your bagel actually coming out “lightly toasted” instead of burnt to a crisp like they always do). But it has not (yet) cut the Gordian cinnamon knot. It has also raised profound questions of its own: Can breakfast truly occur “any time?” Can we ever know for certain what’s in the Denver Omelette? Can my order of huevos rancheros really affect your decision to just get the individual grapefruit half? Are donuts only there when we look?⁹

The failure of science to find coherent answers has led some scholars to theorize that breakfast may not exist at all.¹⁰ Rather they suggest that our experience of breakfast may be no more than a persistent illusion—that in fact, nothing truly exists beyond the bacon, eggs, toast, hash browns, coffee, and perhaps a fruit cup. Our brains falsely attribute the quality of breakfast to these items, perhaps to encourage us to eat them and thereby nourish ourselves. The evolutionary psychologist Danika Saunders has recently proposed in a series of papers that our ancestors who developed the ability to breakfast may have enjoyed a survival advantage over their non-breakfasting peers, such as being better able to outrun wolverines.¹¹

Can we ever know for certain what's in the Denver Omelette?

More intriguing still, if somewhat disconcerting, is an idea first proposed by Lipton and Singh¹²: that the dishes themselves may have evolved the capacity to trick our brains into experiencing them as breakfast, perhaps in an effort to perpetuate themselves by encouraging us to get up and make them. This of course raises many confounding philosophical questions of determinism and free will, such as the one famously posed by the esteemed former chair of the Nutritional Philosophy department at Yale, Roderick T. Dale, to a table of graduate students with whom he was breakfasting: “Did I just order the waffles—or did the waffles order me?”

Three hundred and fifty years have now passed since Newton first speculated about the arising of breakfast from ingredients.¹³ Yet we appear no closer to answering The Hard Problem of Breakfast. What is this mystery of bacon, eggs, oatmeal, and avocado toast? Why does it exist, and how does it emerge each morning to delight us with its flavors, colors, and aromas? Perhaps we will never know. Or perhaps, someday, some brilliant young scholar will finally, definitively “crack the egg” ... and we can move on to lunch. ☺

JONATHAN BINES is a staff writer for *Jimmy Kimmel Live*.

FOOTNOTES

1. Baker, L. *Breakfast Unleashed: The Technological Revolution That Changed What We Eat Before 11:00AM Forever* (2015).
2. Dell, P. Scientists Still Waffle on Origins of Breakfast. *Newsweek* (2019); also, Renery, D. Breakfast: Epiphenomenon, Artifact, or Adaptation? *Bulletin of the Gastronomic Scientists* **804** (2012).
3. See, for example, Pinsky, F. “Where The Hell Is My Grand Slamwich?” *Denny’s* (2009).

4. Brain scans have detected the so-called “neural correlates” of breakfast, neuronal activity correlated with, say the consumption of a cantaloupe. But these fail to explain why there is “something that it is like” to eat cantaloupe. Or as Philosopher David “Lucky” Chalmers puts it: “We may one day build an android capable of eating a blintz. But *would it taste the cheese?*”
5. Scherzinger, *et al.* No Yolk: Eggs “Egg-scluded” as Physical Basis of Breakfast *American Journal of Dietary Physics* **208** (2007).
6. See, for example, Davidson, M. “Quiche Any Time! 12 Quick And Easy Recipes that Rule Out Eggs As a Mechanism For the Emergence of Breakfast”
7. Morris D. & Shrenk R. That Time We Got Baked and Ordered Every Breakfast at IHOP. *Reddit* (2009).
8. An excellent summary can be found in Martinez P. *Who Had The Grits? Uncertainty, Probability and the New Physics of Breakfast* (2009); also see Bohm, D. *Wholeness and the Implicate Side Order of Whitefish* (2014); and Mye, A. *Schrödinger’s Crêpe* (2006).
9. To address these concerns, Gustaf Togue of the Institute for Advanced Eleggtrodynamics has recently proposed the “Many Orders” theorem, interpreting the equations of quantum breakfast to conclude that no specific breakfast is ever chosen; rather, at the time of ordering, every possible breakfast is selected in one of multiple split-off restaurants that exist independently but can never communicate with one another (which explains why only one particular breakfast ever appears on the bill).
10. Davis, E. I Skipped Breakfast For 30 Days and Here’s What Happened. *Huffington Post (Personal)* (2019).
11. Saunders, D. Breakfast as an Evolutionary Adaptation to Wolverine Predation. *Cornell University Journal of Evolutionary Psychology and Wild Guesses* **414** (2012).
12. Lipton, Y., & Singh, D. Are Humans Just Breakfast’s Way of Making More Breakfasts? Maybe! *Waffle House Science Quarterly* **6323** (2011).
13. Writing to his friend Henry Oldenburg in a 1672 letter: “To determine by what modes or actions bacon produceth in our minds the phantasm of flavour is not so easie.” Two hundred years later, Biologist T.H. Huxley would express much the same perplexity, writing, “What breakfast is, we know not. Also, *where* it is. I’m friggin’ starved.”



Just Because It's Natural Doesn't Mean It's Good

We are well advised to not lose track of evolution's dark side

BY DAVID P. BARASH

W

HAT DO ANTI-VAXXERS and anti-GMO campaigners have in common? Underpinning both “antis” is a shared belief that because vaccines and GMOs are “unnatural,” they’re bad, which for many people—whatever their feelings about vaccines and GMOs—segues into its inverse: What’s natural is good. Shades of Rousseau’s exaltation of the noble savage, within us and without.

It's an easy conclusion, often appropriate. Given a choice, most people gravitate toward the natural over the artificial. After all, natural environments are preferable to garbage dumps, natural foods are nearly always healthier than stuff concocted in a chemistry lab. Yet it needs to be said loud and clear: Just because something is natural doesn't mean it's good. "Smallpox is natural," Ogden Nash noted. "Vaccine ain't." Gangrene, acne, hurricanes, earthquakes, COVID-19—all bona fide natural.

Reading 19th-century critic and essayist John Ruskin, who wrote "There is no such thing as bad weather, only different kinds of good weather," one cannot help conclude that Mr. Ruskin didn't get out much. By the same token, "doing what comes naturally" can be very bad advice indeed.

"All nature is but art," Alexander Pope wrote in *An Essay on Man*. "One truth is clear, Whatever is, is right." Pope's conviction, embedded in social philosophy, remains ingrained in our culture today. I disagree, and so would most of my biologist colleagues, who, like me, have spent their careers admiring and seeking to understand the complexities and wonders of the epitome of the natural: evolution.

Evolution by natural selection is an endlessly fascinating phenomenon. Having produced all living things, it deserves our gratitude, while its power and subtle complexity repay scientific scrutiny. But we'd be well advised to not lose track of its dark side, and certainly not to mistake its naturalness for any sort of ethical bona fides.

EVOLUTION IS—in Pope's sense—but that doesn't make it right. Physicists have never proposed that the law of gravity, the increase in entropy, or the various electromagnetic "rules" that hold sway among subatomic particles should be consulted as a source of ethical good. Otherwise we ought to crawl on our bellies, hold fast to anything different from ourselves—as positive adheres to negative—and never clean our rooms. Natural selection, the driving force of evolution, is every bit as natural as Newton's laws, the second law of thermodynamics, or quantum mechanics, and every bit as devoid of moral direction. Like the laws of physics, the laws of biology simply describe what is, not what should be.

Evolution is a wonderful thing to learn about, a terrible thing to learn from.

When it comes to humane values the evolutionary process is, if anything, not so much neutral as negative; it is likely to lead to results that most ethicists will and should reject. It is a wonderful thing to learn *about*, a terrible thing to learn *from*. Evolution is as natural as a vaccine-generated immune response or the array of genes that can be modified by human intervention—in a sense, more so, as it has produced both the immune system and the genes themselves. If it's the artifice of artificial selection that is deplorable to some, just wait until we take a clear-headed look at natural selection in all its naturalness! A moral exemplar it isn't.

Our current understanding of natural selection is that it operates as a ratio, with the numerator reflecting the success of genes in projecting copies of themselves into the future and the denominator, the success of alternative alleles. Since a gene (or an individual, a population, even—in theory—a species) maximizes its success by producing the largest such ratio, it can do so either by reducing the denominator or increasing the numerator. Most creatures, most of the time, find it easier to do the latter than the former, which is why living things generally are more concerned with feathering their nests than de-feathering those of others.

Taken by itself, such self-advancement isn't the stuff to make an ethicist's heart go pitter-pat. But to make matters worse, animal studies in recent decades have revealed a panoply of behavior whereby living things have no hesitation in minimizing the denominator, trampling over others in pursuit of their own biological benefit. We have long known that the natural world is replete with grisly cases of predation, parasitism, a universe of ghastly horrors all generated by natural selection and unleavened by the slightest ethical qualms on the part of perpetrators.

In *Pilgrim at Tinker Creek*, Annie Dillard described her horror at watching a frog whose innards were liquefied and then sucked dry by a giant water bug. Dillard also shared her puzzled outrage at the phenomenal wastefulness of an evolutionary process that generates hundreds, often thousands of tiny but perfect lives, only to snuff most of them out, relentlessly and heartlessly.

Worse yet, perhaps, are the cases of vicious genetic self-promotion at the expense of others—not content with enhancing the numerator, but actively diminishing the denominator.

Biologists have documented infanticide in numerous species, including lions and many nonhuman primates such as langur monkeys and chimpanzees. The basic pattern is that when a dominant male dies or is overthrown, his replacement often systematically kills the nursing infants (those unrelated to himself). The process is typically a bloody, grisly affair, frequently playing out over several hours or even days. But it is clearly adaptive for the murderous, newly ascendant male, because he has no evolutionary interest in the fate of these unrelated youngsters, and, moreover, their mothers stop lactating and are available to mate

NOT A ROLE MODEL Biologists have documented infanticide in numerous species, including chimpanzees.

The process is a grisly affair. But it is clearly adaptive for the murderous, newly ascendant male.



with their babies' murderer. When first described by primatologist Sara Hrdy, even hard-eyed biologists had a difficult time accepting the ubiquity of male-takeover infanticide, and even—until recently—its “naturalness.” Perhaps, they suggested, it was induced by unnatural protein deficiency, or by equally unnatural crowding. But natural it is, and a readily understood consequence of natural selection as a mindless, automatic, and value-free process. Infanticide is immoral by any reasonable human standard, but its driving principle is the blindly amoral process of natural selection, which maximizes evolutionary fitness, no matter how fiendish it appears to the horrified human observer.

Even the evolutionary master himself was appalled on occasion. Writing to his friend, botanist Asa Gray, Darwin was less than delighted with the fact that certain wasps lay their eggs so that the developing larvae feed “within the living bodies of Caterpillars.” A few years earlier, he had complained to Joseph Hooker, “What a book a Devil’s Chaplain might write on the clumsy, wasteful, blundering low and horridly cruel works of nature.”

Add cases of animal rape, deception, nepotism, siblicide, matricide, and cannibalism, and it should be clear that natural selection has blindly, mechanically, yet effectively favored self-betterment and self-promotion, unmitigated by any ethical considerations. I say this fully aware of an important trend in animal behavior research: the demonstration that animals often reconcile, make peace, and cooperate; no less than the morally repulsive examples just cited, these behaviors also reflect the profound self-centeredness of

the evolutionary process. If the outcome in certain cases is less reprehensible than outright slaughter, it is only because natural selection only sometimes works to reduce the denominator of the “fitness ratio.” Most of the time, it increases the numerator. But all the time, the only outcome assessed by natural selection is whether a given tactic works—whether it enhances fitness—not whether it is good, right, just, admirable, or worthy of rainbows and sparkly unicorns.

Gangrene, acne, hurricanes, earthquakes, COVID-19—all bona fide natural.

There exists, nonetheless, a social and philosophical tradition—social Darwinism, championed by the 19th-century sociologist Herbert Spencer (who also coined the term, natural selection)—that sought to derive ethics from evolution. Not surprisingly, it was appealing to the early robber barons (aka “captains of industry”) to think that their success, often achieved by the immiseration of others, was organically preordained. John D. Rockefeller argued that “the growth of a large business is merely a survival of the fittest and ... the working out of a law of nature.” The doctrine of evolutionary ethics is now blessedly in decline, mostly because of a widespread feeling that science and morality represent, as Stephen Jay Gould argued, different and non-overlapping magisteria.

IN VIEW OF EVOLUTION’S DARK SIDE, it would seem reasonable to go further. Insofar as evolution has engendered behavioral tendencies within ourselves, no less than within other animals, that are callously indifferent to anything but self- (and gene-) betterment, and armed as we now are with insight into the origin of such tendencies, wouldn’t sound moral guidance suggest not only that we refuse to fashion our behavior after natural selection’s prodding, but that we intentionally act contrary to them?

It is well within our capacity to say “No” to our evolutionary bequeathal.

In the movie *The African Queen* (based on an even better book by E.M. Forster), Katherine Hepburn stiffly observes to Humphrey Bogart: “Nature, Mr. Allnut, is what we were put on Earth to rise above.” Let’s stipulate that we were not put on Earth to do anything other than to maximize the representation of our genes in future generations. But if we want to be ethical—rather than simply “successful”—rising above our human nature may be just what is needed.

By the end of the 19th century, Thomas Huxley was perhaps the most famous living biologist, renowned in the English-speaking world as “Darwin’s bulldog” for his fierce and determined defense of natural selection. But he defended evolution as a scientific explanation, not as a moral touchstone. In 1893, Huxley made this especially clear in a lecture titled “Evolution and Ethics” delivered to a packed house at Oxford University. “The practice of that which is ethically best,” he stated, “what we call goodness or virtue, involves a course of conduct which, in all respects, is opposed to that which leads to success in the cosmic struggle for existence. In place of ruthless self-assertion it demands

self-restraint; in place of thrusting aside, or treading down, all competitors, it requires that the individual shall not merely respect, but shall help his fellows; its influence is directed, not so much to the survival of the fittest, as to the fitting of as many as possible to survive.”

“The ethical progress of society depends,” Huxley continued, “not on imitating the cosmic process, [that is, evolution by natural selection] still less in running away from it, but in combating it.”

It may seem impossible for human beings to “combat” evolution, since *Homo sapiens*—no less than every other species—is one of its products. And yet Huxley’s exhortation is not unrealistic. It seems likely that to some extent each of us undergoes a trajectory of decreasing selfishness and increasing altruism as we grow up, beginning with the infantile conviction that the world exists solely for our personal gratification and then, over time, experiencing the mellowing of increased wisdom and perspective as we become aware of the other lives around us, which are not all oriented toward ourselves. In *Middlemarch*, George Eliot

noted that “we are all born in moral stupidity, taking the world as an udder with which to feed ourselves.” Over time, this “moral stupidity” is replaced in varying degrees with ethical acuity, the sharpness of which can largely be judged by the amount of unselfish altruism that is generated.

Richard Dawkins’ influential book, *The Selfish Gene*, could reasonably have been titled *The Altruistic Gene*, because evolutionary success is typically achieved by improving the prospects of identical copies of one’s genes contained in other bodies, be they offspring or other genetic relatives. But altruism at the level of bodies is really an evolutionary means of achieving selfish ends for the relevant genes. Even in the unlikely event that altruism is promoted by some benefit experienced by a larger group that encompasses the bodies and genes thereby aided, the process itself would nonetheless be fundamentally selfish, and thus unappealing to most ethicists this side of Ayn Rand.

Many scientists and humanists misunderstand the connection between evolution and morality, grimly determined that evolutionary facts are dangerous because they justify human misbehavior. Developmental psychologist Jerome Kagan exemplified this blind spot when he wrote, “Evolutionary arguments are used to cleanse greed, promiscuity, and the abuse of stepchildren of moral taint.” Similar arguments were in fact used this way in the unlamented days of Social Darwinism.

In fact, evolutionary thinking helps us to understand greed, promiscuity, and the abuse of stepchildren, also shedding light on parenting, nepotism, reciprocity, communication, friendship, parent-offspring conflict, courtship, violence, love, adultery, altruism, and bigotry.

Human beings, more than any other living things, are characterized by an almost unlimited repertoire, a behavioral range that exceeds that of any other living creature. It is well within our capacity to say “No” to our evolutionary bequeathal, especially once we recognize its unethical underpinnings. After all, we engage in all sorts of activities that are unnatural but good. Some of them require going against certain human inclinations, and, although not easy to achieve, are readily within the human repertoire once the social and personal benefits are made clear, and compliance demanded. Others, like playing the violin, learning a second language,

composing a novel, even writing an article for *Nautilus*, require effort and dedication. In this sense, once again, they’re not “natural” like sleeping when tired or eating when hungry. But they’re not only achievable, they can be some of humankind’s greatest accomplishments, natural or not.

A case can be made that those human accomplishments that are greatest, most noteworthy, most lasting and sublime, are those that are achieved when people act contrary to their “natural” inclinations. “Drink when you are not thirsty,” we are advised in Mozart’s opera, *The Marriage of Figaro*. “Make love when you don’t want to—this is what distinguishes us from the beasts.” Whatever the wisdom of drinking or making love when disinclined, it’s hard to argue that writing an opera—unnatural as it may be—isn’t nonetheless good.

The point is this: Whatever our biological tendencies for selfish, unethical, altogether “natural” behavior, there is reason for optimism about our capacity to rise above such inclinations, especially if we recognize the wisdom of doing so. Not everyone is cut out to compose great opera, but the good news is that every human being—simply by being human—can rise above some of evolution’s more unpleasant bequeathals. “We Shall Overcome.” Indeed, the capacity to overcome is what it means to be human. ☺

DAVID P. BARASH is an evolutionary biologist and professor emeritus of psychology at the University of Washington. His most recent book is *Threats: Intimidation and its Discontents*. Parts of this article are drawn from his 2007 book, *Natural Selections*.



A decorative graphic on the left side of the page. It features two pills: one is white with an orange band, and the other is entirely orange. Below the pills is a large, solid red circle. The background of the entire page is a dark, textured purple.

Show Me How to Say No to This

How drugs today can cure a crushing love

BY BRIAN D. EARP & JULIAN SAVULESCU

IN THE 2004 FILM, *Eternal Sunshine of the Spotless Mind*, a heartbroken man played by Jim Carrey undergoes an experimental treatment to erase memories of his ex-girlfriend, played by Kate Winslet, following their painful breakup. When the film came out, using drugs or other technologies to meddle with memory, especially as a way of healing from a traumatic relationship, was not exactly feasible in the real world.

Early this year, though, a real-life technique for memory modification in response to heartbreak hit the newsstands. The coverage centered on Alain Brunet, a psychiatrist and expert in post-traumatic stress disorder at McGill University in Montreal, Canada. In his lab, Brunet works with victims of what he calls “romantic betrayals.” These can range from harassment by a former lover to sudden abandonment by a long-term partner. He uses a technique known as reconsolidation therapy, which combines a drug-based treatment with practical exercises to change the emotional content of disturbing recollections. “We don’t treat the symptoms,” Brunet says of his method, “we treat the memory.”

GEARSTD / SHUTTERSTOCK

Unlike the fictional staff of Lacuna, Inc., the memory-erasure firm in *Eternal Sunshine of the Spotless Mind*, Brunet and his collaborators stop short of trying to “delete” traumatic memories altogether. “You don’t forget your memory,” Brunet stresses, asking, “Who would want to forget their love story?” Rather, the goal of the therapy is to keep the memory intact while removing its traumatic aspects. Here is how this works:

An hour before a therapy session, the patient is given a dose—between 50 mg and 80 mg—of a beta-blocker called propranolol, and is asked to write a summary of the traumatic experience, following a strict format: a first-person text in the present tense that describes at least five physical sensations felt at the time of the event. By reading the summary out loud, the patient “reactivates” the memory, and does so over four to six weekly sessions, under the influence of propranolol. At every reading, the memory is “recorded again” while the drug suppresses the pain it contains.

The therapy has a good success rate. More than 70 percent of participants in a 2018 study conducted by Brunet and his colleagues reported meaningful relief from their breakup-related stress. Following treatment, many patients said reading through the details of their memory felt like “reading a novel.” In other words, the narrative remained, but the pain was gone.

Love and heartbreak often go together. Sometimes, the suffering that comes with the end of a relationship helps us grow. It can force us to slow down, reflect on what happened, and learn to avoid repeating past mistakes. But other times, the suffering just crushes our soul. The pain becomes too much to bear, and it prevents us from moving on with our lives or opening ourselves up to positive relationships.

If we can use the tools of medicine, including drugs and psychotherapy, to treat the trauma of a broken heart—could we use it to cure ourselves of unrequited love or a love gone bad?

According to the philosopher Carrie Jenkins, love has a “dual nature.” One aspect is psychosocial: love as we experience it, subjectively, within a particular cultural and historical context. This is where art, literature, music, philosophy, and poetry shed light on love. The other aspect is biological: Love as it is rooted in our

It’s a real-life technique for memory modification in response to heartbreak.

animal nature, emerging from the mating and bonding mechanisms that drive our species to reproduce. Science can help us make sense of this dimension.

Modern neuroscience traces the biological side of love to the brain specifically. In 2008, one of us (Julian) along with our good friend and colleague Anders Sandberg, published the first-ever discussion of the science and ethics of chemically enhanced love and relationships. This account focused on the potential use of biochemistry to help maintain a good and worthwhile relationship that might otherwise needlessly break down. The following year, writing in *Nature*, the neurobiologist Larry Young raised the possibility of pushing love in the opposite direction with a chemical cure.

As Young sees it, love is essentially “a cocktail of ancient neuropeptides and neurotransmitters.” He argues that “drugs that manipulate brain systems at whim to enhance or *diminish* our love for one another may not be far away.” Although we agree with Young’s general point, we think it would be better to say that the *biological* dimension of love is an emergent property of an ancient chemical cocktail, whereas the *psychosocial* dimension of love emerges from practices, cultural norms, and institutions embedded in societies. With this clarification in mind, what kinds of drugs could be added to the biological cocktail to bring about the effects Young speaks of?

TO MAKE SENSE of the different options, let’s organize them around three distinct brain systems that some researchers argue form the biological building blocks of romantic love: lust, attraction, and attachment. Each of these is thought to serve a different evolutionary purpose, and each can (and does) function somewhat independently in humans and other mammals.

Drugs acting on the lust system are already available. They include antidepressant medications,

androgen blockers, and oral naltrexone. We can also add a few household examples, namely tobacco and alcohol. And then there is a range of other drugs with libido-weakening effects among their potential outcomes. These include almost all blood pressure pills, pain relievers containing butalbital as well as opiates such as morphine and hydrocodone, statin cholesterol drugs, certain acid blockers used to treat heartburn, the hair loss drug finasteride, and seizure medications including gabapentin and phenytoin. With the exception of androgen-reducing drugs used specifically for chemical castration (sometimes applied to serious sex offenders), the negative effects of these substances on a person's sex drive are typically neither intended nor desired. Yet that doesn't have to be the case.

What is the mechanism of these drugs? Basically, it is regulation of testosterone. Focusing on this hormone as one important biological factor behind sexual desire and behavior, a number of studies have measured the effects of reducing testosterone on problematic sexual thoughts or activities—mostly in men—such as intrusive erotic fantasies or compulsive exhibitionism (like flashing random strangers in the park). One study, for example, reported that cutting testosterone levels led to a reduction in pedophilic sexual fantasies and urges among some men. Likewise, the neuroscientist Till Amelung looked at the combined effects of androgen deprivation therapy and group psychotherapy on a small sample of “self-identifying, help-seeking pedophiles,” and reported a reduction of inappropriate sexual behaviors, an increase of risk awareness and self-control, and a dampening of thoughts that tend to correlate with pedophilic actions.

Side effects are a huge problem with these drugs. In one study, antiandrogen drugs were given to hospitalized patients struggling with a range of paraphilic conditions. These included pedophilia, voyeurism, public masturbation, compulsive hiring of prostitutes (or sex workers) and use of peep shows, “tendency to commit rape,” and unwanted masochistic desires. The researchers reported positive outcomes in a number of cases and concluded that one of the drugs they used “shows promise as a treatment for paraphilias.” But complications occurred in each of the 12 cases described: One patient experienced nausea and vomiting; some lost the ability to ejaculate or have an erection altogether;

Being in love literally induces a state which is not normal.



ROMEO AND JULIET. AFTER AN ORIGINAL PAINTING EXHIBITED AT THE PARIS SALON IN 1908. FROM A PHOTOGRAPH BY SEWIDRIN

Mademoiselle A. Oppenheim, Painter

O TRUE APOTHECARY!

Literature would not have its great tragedies without heartbreak. But authors Brian D. Earp and Julian Savulescu argue that modern chemistry can spare the real-life pain of heartbreak today.

others showed a complete absence of sexual feeling or interest and became severely depressed; and every patient subjected to prolonged treatment suffered bone mineral density loss, putting them at risk for osteoporosis.

Another problem with anti-androgen drugs is that their effect on a person's libido is typically global rather than selective. Imagine that you wanted to reduce only harmful or ill-directed lust—toward a prepubescent child, for example, or an adult who was tempting you away from your well-considered monogamous commitment. You would likely be disappointed. Current biotechnology is not sensitive enough to reliably deliver on these sorts of person-specific goals.

ANTI-ATTRACTION DRUGS are a bit trickier. For one thing, interventions into the attraction system are less studied than those that primarily affect libido. Some blunt chemical instruments currently exist, but the nature of what makes a partner attractive in the first

place is little understood and is likely to be highly variable. Insofar as they could be shown to work, anti-attraction drugs would probably reduce the obsessive thoughts characteristic of early-stage romantic relationships, or the chance that an initial spark of attraction would lead to longer-term attachment.

Donatella Marazziti is an Italian neuroscientist based at the University of Pisa. She has been trying to find out whether serotonin might play a role in early-stage romantic attraction. Her hunch came from observing that this all-consuming period, characterized by obsessive thought patterns and nervous preoccupation with the tiniest of details (similar to what can happen with jealousy as well), might have more than a passing resemblance to obsessive-compulsive disorder, or OCD, which has already been linked to low levels of serotonin. The idea was that the “same lack of serotonin that results in an OCD patient's believing that touching a door five times upon entering can guarantee safety may also be behind the way

you constantly, compulsively think about a new squeeze when you are in the honeymoon phase of a relationship.”

As she predicted, participants who had recently fallen in love—still in the intense first stage of a relationship but prior to having sex—had levels of serotonin similar to those of a sample of OCD patients, both groups having lower levels than healthy controls. As Marazziti and her coauthors conclude, “It would suggest that being in love literally induces a state which is not normal.” Indeed, retesting the lovers at 12 to 18 months revealed that serotonin levels had returned to baseline, at which point their “obsessive ideation regarding the partner” had disappeared as well.

Given the findings of Marazziti and colleagues, one possibility is that drugs used to treat OCD could dampen at least the obsessive aspects of a nascent amorous relationship. As it happens, patients with OCD respond most reliably to selective serotonin reuptake inhibitors (SSRIs), that same class of antidepressants whose ability to diminish the sex drive is now well known. SSRIs can also sometimes lead to “emotional blunting” of higher-level feelings involved in romantic attraction and relationships generally: 80 percent of SSRI-using patients in one study “reported less ability to cry, worry, become angry or care about others’ feelings.”

Again, if you’re trying to maintain a relationship, not caring about your partner’s feelings is a lousy idea. If you’re trying to end a relationship or keep it from developing into something more, however, maybe this type of treatment could grease the wheels.

FINALLY, ANTI-ATTACHMENT interventions. There isn’t a whole lot of concrete evidence that existing technologies could completely sever a long-term human pair bond, although breakdowns in attachment obviously happen on their own all the time (just ask anyone who has gotten over their ex). There is, however, compelling evidence for such a possibility in other mammals with analogous mating habits—namely, voles. Studies have shown that injecting the brain chemical oxytocin, which is crucial to forming the attachment bond between parents and their infants as well as between adult mating partners, could foster a pair bond

in at least one species of vole without any actual mating. And crucially for our purposes, this kind of effect could be reversed.

In one study, injecting female prairie voles with either an oxytocin or a dopamine blocker caused them to lose their monogamous tendencies; that is, they failed to show any partner preference as a function of copulation. As Larry Young put it: “They will not bond no matter how many times they mate with a male or how hard he tries to bond. They mate, it feels really good, and they move on if another male comes along.” Likewise, pair-bonded male prairie voles injected with a dopamine blocker—at a specific site in the brain known as the nucleus accumbens—failed to show characteristic mate-guarding behaviors and became more receptive to interactions with novel females.

Most scientists who study human attachment believe that something like the prairie-vole bonding mechanism is preserved in mammals over evolutionary time and shows up in our species as well. Nevertheless, we are not aware of any scientists who have injected blockers for oxytocin, dopamine, or any other neurochemical into the brains of human subjects to find out what happens to their romantic attachments. Not only would this be hard to justify to a university ethics committee; it would also presumably not inspire many volunteers.

There may be a way around this scientific hurdle. Consider a 2019 headline from *VICE* magazine: “How to Bio-Hack Your Brain to Have Sex Without Getting Emotionally Attached.” The author, Sirin Kale, writes about an “an all-too-familiar situation for many people: You decide to have sex with someone whose personality you find repugnant, whom you have no interest in dating, only to find yourself bizarrely attached to them in the morning.” Now, one thing you could do to avoid this situation is to think twice about going to bed with someone whose personality repulses you. But suppose it’s too late for that, and you’re already deep in the ardent throes of your dubious decision. Can you somehow immunize your brain against its own tendency to form a sex-based emotional attachment?

According to Young, you can. The trick is to avoid eye contact with your partner during sex. Research shows that prolonged eye contact causes the release of oxytocin in the brain; this, in turn, increases the

People are afraid of pathologizing love.

chance of forming a bond. “When you’re having sex with someone,” Young explains, “you’re making an intimate connection with their face and eyes particularly. This is going into your brain, and it’s inherently rewarding. Love and attachment are very much like addiction. They have a lot of the same chemicals. So if you can divert that information from coming in by not having that eye contact, that will help.”

Certain illicit drugs may “help” as well. According to Young, cocaine and methamphetamine boost dopamine secretion, which is also involved in pair bond formation. If you take a drug to raise your dopamine levels “prior to an intimate moment,” he says, “it won’t have the same impact later. The specialness of the sex, and the differential caused by the dopamine release won’t be so high.”

Finally, alcohol can foster attachment-free sex (which might be one of the reasons why they often go together). But the disruptive effect of alcohol on pair bonding seems to be different for males and females. At least, that is how it seems in the case of voles. “When male voles drink alcohol they become promiscuous and it prevents them from bonding,” Young says. For female voles, it is exactly the opposite. Alcohol “increases the likelihood they will bond prematurely.” Voles in the wild are not usually big on alcohol. So you can guess that these findings come from a lab.

Another, more speculative lead for an attachment-dissolving intervention comes from a medical condition known as Capgras’s delusion. In this tragic delusion, an individual reports believing that a spouse, sibling, or close friend has been replaced by an imposter who shares identical visual features. Patients suffering from this condition are able to recognize faces, but the automatic emotional connection to familiar faces that most of us experience just doesn’t come online. That lack of emotional connection leads to the belief that the person must be an imposter.

One explanation for this phenomenon is that neuroanatomical pathways responsible for responding to familiar visual stimuli have become damaged or degraded. This account fits nicely with the oxytocin-dopamine model of attachment, which involves combining social-identity cues (such as the physical features of a person) with a network of positive emotions.

Anti-attachment interventions of the future, then, might mirror the Capgras syndrome—ideally without inducing its delusive aspects—by interfering with this integration in a targeted way.

TAKEN TOGETHER, THESE FINDINGS suggest that it may soon be possible to block or diminish lust, attraction, and/or attachment using pharmacological strategies. In fact, it is already possible to achieve some of

these effects, if in a blunt and haphazard way. One question this raises, then, is whether these current, messy drugs should ever be used to affect relationships, notwithstanding the risk of various side effects and the fact that most of these uses would be off-label.

The ethics of prescribing drugs off-label is tricky. Sometimes the evidence concerning appropriate doses, benefits, and risks has changed since the manufacturer's label was finalized. If you're prescribing a drug for the purpose it was originally intended for, in a way that is consistent with the best available evidence, and the evidence just happens to have changed since the label was printed, hardly anyone would seriously object.

On the other hand, if you're prescribing a drug for a purpose it was *not* originally intended for, the most likely scenario is that there won't be enough high-quality evidence concerning the effects of the drug for that use. You might then be exposing the patient to unknown harms, which weighs against the practice.

However, the drugs we currently use for individualized symptoms are *already affecting* our relationships, but in ways and under conditions about which we are mostly clueless, because the evidence base consists primarily of case studies and anecdotes. Sure, you can approach treatment for someone dealing with extreme jealousy, as one psychiatrist reportedly did, "as if" the patient had OCD—and cross your fingers that he stops haranguing his wife. So long as you have a plausible on-label use for the drug that just happens to be associated with a person's relationship difficulties, you are probably good to go. But we should be going about this in a much more cautious, scientific way.

Why aren't we? What's stopping us from deliberately researching the interpersonal effects of common medications, both good and bad? One reason is that people are afraid of pathologizing love and relationships. Since doctors are only allowed to prescribe drugs that society regards as medicine, and since medicine is typically used to treat patients who have some kind of disease or disorder, the fear is that prescribing a drug to help someone's intimate relationship would imply that the relationship is pathological—when maybe it's just down to hard times.

This fear is understandable given the current paradigm. But the paradigm needs to change. Drugs are just chemicals. You can call them medicine, but chemicals

don't know if you have a disease they're supposed to be treating (so that they can somehow confine themselves to acting only within the definition of that disease). Instead, they just do whatever they do, whether you intended them as a cure for a pathology or just believe they could improve your life.

We should be open to the idea that certain chemicals can increase people's happiness or well-being, on balance and under the right conditions, without our first having to invent a disease for those chemicals to be addressing. One particularly promising area for this idea concerns the recent explosion of scientific and medical research into psychedelic drugs (like "magic" mushrooms) for both treatment and enhancement purposes. On the treatment side, there is growing evidence that psychedelic-assisted psychotherapy can help some people with otherwise incurable PTSD get their lives back. And on the enhancement side, such therapy has had positive effects in healthy individuals who then feel better able to navigate the vagaries of life. In the case of improving relationships, the idea is not to subsume yet another domain of ordinary human existence under the disease labels of medicine so that people can gain access to certain drugs. Instead, it would be to take certain drugs out of the domain of disease labels and ask whether they could improve certain aspects of relationships. ☺

BRIAN D. EARP is the associate director of the Yale-Hastings Program in Ethics and Health Policy at Yale University and the Hastings Center, and a research fellow in the Uehiro Centre for Practical Ethics at the University of Oxford.

JULIAN SAVULESCU holds the Uehiro Chair in Practical Ethics at the University of Oxford and directs the Oxford Centre for Neuroethics.

Excerpted from *Love Drugs: The Chemical Future of Relationships*, by Brian D. Earp and Julian Savulescu, published by Stanford University Press, ©2020 by Brian D. Earp and Julian Savulescu. All Rights Reserved.



The Price of Life Is Death, but Sex Improves the Exchange Rate

Calculating the evolutionary success of Homo sapiens

BY AARON HIRSH

EPIDEMICS HAVE A WAY of making one wonder about death. To put it plainly, in the raw form it takes as it first rises from our hearts: *Why?* Why on Earth does it have to be this way?

In *The Plague*, Albert Camus' novel of harrowing disease in an Algerian city, Father Paneloux, a faithful Jesuit, steps to the pulpit and offers his explanation. "This same pestilence which is slaying you," Paneloux says, "works for your good and points your path." In another sermon, Paneloux goes further: "The suffering of children was our bitter bread, but without this bread our soul would perish from its spiritual hunger."

A young Charles Darwin, too, wondered about this problem, and for a while, he thought perhaps he had found an answer. Indeed his argument had something in common with Paneloux's sermon: Death and suffering were linked inescapably to a higher good, though Darwin's good was different from Paneloux's. Where the Jesuit placed spiritual direction and nourishment, Darwin inserted the evolution of wondrous living things. The final paragraph of *On the Origin of Species* includes this remarkable sentence: "Thus, from the war of nature, from famine and death, the most exalted object which we are capable of conceiving, namely, the production of the higher animals, directly follows."

*How many
useful deaths
did it take to
transform the
chimp-human
ancestor into
Homo sapiens?*

What Darwin did not realize is that sex tips the calculations strongly in our favor.

Setting vast spiritual questions aside, there is a narrow sense in which Darwin was perfectly right: Embedded in the theory of evolution by natural selection is the idea that life is paid for with death. I mean this not in the poetic or sentimental sense that the price we pay for our time here on Earth is the sadness of our final departure. I mean it, rather, in the more prosaic and definite sense that the attributes we observe and admire in living creatures—precise adaptive fit to an environment, intricacy of construction, astonishing and diverse capabilities—are all built by a process that requires a certain quantity of death.

One can even calculate, under reasonable assumptions, just how much death. What Darwin did not realize, as he formulated his theodicy, is that sex tips the calculations strongly in our favor.

IN MATTERS OF LIFE AND DEATH, we ought to be precise, so consider a simple example, the sort of scenario theoreticians would call a toy model. Imagine a species that consists of 100,000 individuals, living in Edenic and equitable balance with their resources. Every individual gets to produce exactly one offspring, replacing him or herself in the population. Lovely. But what must become of this Eden if the species is to evolve?

Say one individual is born with a beneficial genetic mutation—a change in her material of inheritance, her DNA, that makes her better adapted than all her peers. She can hide better or forage faster; hunt more effectively or battle more powerfully—whatever the mutation is, it gives her a leg up.

For this new mutation to climb in frequency from 1 in 100,000 to 2 in 100,000, the individual who carries it must produce not one but two offspring. But the population, we've said, is held steady, by some limited resource, at 100,000 individuals. So for one extra individual bearing the new mutation to enter the population, one extra individual who does not bear the new

mutation must die, making room for improvement, so to speak. More generally, one extra death is required for each incremental increase in the beneficial mutation's prevalence. For the new mutation to increase by 1 percent in our population of 100,000, 1,000 extra deaths must occur. For the new mutation to be shared by the whole population—for it to go to *fixation*, as evolutionary biologists would put it—100,000 extra deaths must occur. Thus, the dues of evolution are paid in the currency of death.

We ought to add some nuance. For each incremental increase in the frequency of the beneficial mutation, it's not technically a death that's called for, but only the failure of one individual to survive and reproduce. Maybe someone just doesn't get to have her allotted offspring. The point is only that the parent's genetic lineage must come to an end. But in nature, that usually means mortality for either the prospective parent or the offspring. A reasonable shorthand is, well, just death.

When we add just a bit more biological realism to our toy model, the situation looks grimmer still. As you may recall, nearly all animals are diploid, meaning they carry two copies of their genome. Many new mutations are only semi-dominant—that is, they compromise with the other copy in their host's genome in determining the way the host looks or acts. The great population geneticist J.B.S. Haldane wrote down a simple mathematical model to estimate how many extra deaths would be required for a new advantageous mutation to spread through the whole population of a diploid organism. Using our toy model just a moment ago, we reasoned that the number of extra deaths, spread over the entire history of the evolutionary change, would be about equal to the population size in any single generation (our 100,000). In his model of diploids with semi-dominant mutations, Haldane found that the number was more like 30 times the population size in any single generation.

WHAT I'VE BEEN REFERRING TO as “extra” deaths could also be called “useful” deaths, for they are the deaths that cause an uptick in the prevalence of a beneficial mutation; the deaths that, from an evolutionary point of view, aren't for nothing.



Instead of our imaginary and idealized species of 100,000 individuals, let's consider a real example. The most recent common ancestor of chimpanzees and humans was an ape that moved on all fours, had a skeleton a lot like a modern chimp's, and, perhaps most important of all, had a chimp-sized brain, not our inflated *sapiens* brain. To a very close approximation, all the evolutionary changes that transformed our chimp-human ancestor into modern humans involved genetic mutations increasing in frequency in the population of proto-humans. So how many useful deaths did it take to transform the chimp-human ancestor into *Homo sapiens*?

We don't know exactly how many mutations were favored by natural selection as the chimp-human ancestor evolved into modern *Homo sapiens*. But for purposes of this argument, we don't really need an exact number, just a reasonable, order-of-magnitude estimate, and that's perhaps within reach. Based on recent published analyses of human and chimp genomes, I did a back-of-the-envelope calculation to estimate the number of positively selected mutations in the lineage that leads from the chimp-human ancestor to humans. I came up with 100,000. (Said envelope, in case you're interested, can be read on pages 93 and 94.)

Genomic analysis can also (rather amazingly) give us an estimate of the population size along the lineage from the chimp-human ancestor to humans. Obviously, this number changed a lot over the course of the millions of years it took for the chimp-human ancestor to give rise to *Homo sapiens*. There were periods of expansive population as well as severe bottlenecks. A reasonable middle-ground is on the order of 50,000.

HIGH FREQUENCY Evolutionary changes that transformed our chimp-human ancestor into modern humans involved genetic mutations increasing in frequency in the population of proto-humans.

Back of the Envelope

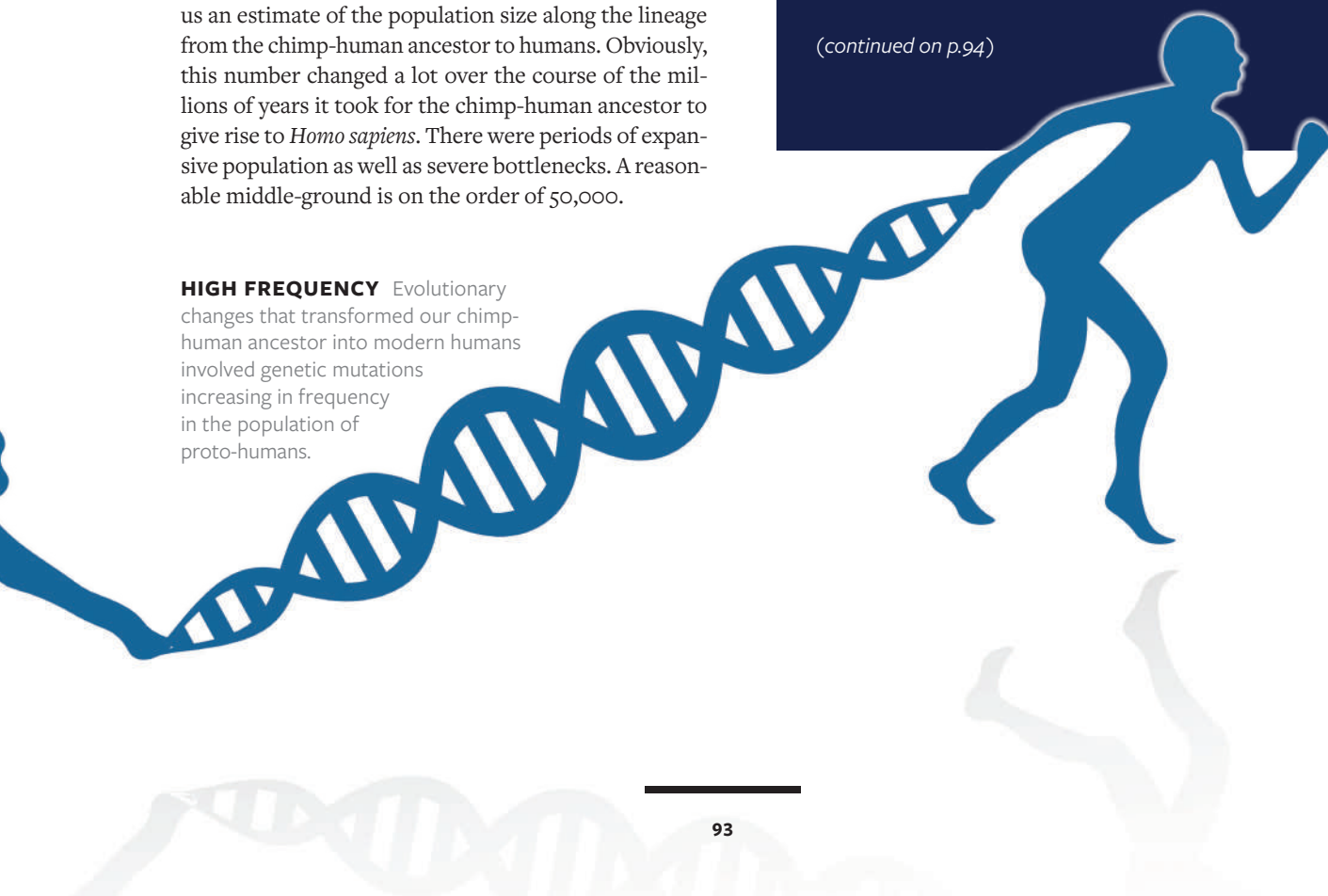
We want to do our best to estimate (very roughly) how many positively selected mutations there have been in the lineage leading from the chimp-human ancestor to humans.

There are about 30,000 non-synonymous substitutions in protein-coding genes between chimps and humans.⁴ For protein-coding regions, a widely circulated estimate is that 10 to 20 percent of amino acid differences between humans and chimps have been fixed by positive selection.¹ This estimate itself rests on a lot of big assumptions, but it is consistent with some other studies of samples of proteins, and probably reasonable.

So that's (30,000 non-synonymous substitutions) * (0.15 positively selected) * (0.5 along the lineage leading to humans rather than chimps) = 2,250 positively selected mutations driven to fixation.

Functional regulatory regions appear to compose at least 7 percent of the genome.¹¹ They evolve faster than protein-coding genes, and the fraction of changes that are positively selected is likely higher. The evidence for this is that the rate of sequence turnover events (defined as loss or gain of purifying selection) in regulatory regions is 2.5

(continued on p.94)



(continued from p.93)

turnover events per neutral substitution, whereas it is 0.23 turnover events per neutral substitution in coding regions.¹¹ This would seem to suggest that regulatory regions are extremely active in evolution, and therefore we could expect a significantly higher fraction of positively selected mutations than we see in coding regions. This is also consistent with studies of specific regulatory regions in model organisms as well as humans.^{4, 5, 7, 9-11} This is clearly the roughest guess of our calculation, but in conversations with population geneticists, I heard estimates of the rate of selectively driven divergence within functional regulatory regions that ranged from one-tenth of the neutral rate up to the neutral rate. (The idea is not that functional regulatory regions are neutral, but that they are subject to purifying selection on certain sites and positive selection on other sites, which together balance out to something approaching the neutral rate.) If we assume the rate is one-tenth the neutral rate of divergence, we have:

$(3.2 \text{ billion base pairs}) * (0.07 \text{ functional regulatory fraction of genome}) * (0.001 \text{ positively selected mutations, which is one-tenth the neutral rate}) * (0.5 \text{ on the human lineage}) = 112,000.$

An interesting implication here is that substitutions within protein-coding sequences are a very small part of evolutionary change compared with evolution outside of protein-coding sequences, in functional regulatory sequences.

Multiplying 100,000 positively selected mutations by Haldane's 30⁶ by the population size of 50,000^{3, 12} for each substitution gives you 150 billion useful deaths. If most evolution is due to selection on standing variation instead of new mutations, you can cut this number in half (very roughly, of course).

The number of generations is 7 million years⁸ divided by 20 years per generation,⁹ equals 350,000. The total number of deaths in the lineage leading from the chimp-human ancestor is the number of generations times the population size of 50,000, equals 17.5 billion.

All of these numbers are *preposterously* rough, but you see the general point. Unless we think about the effect of sex, there hasn't been enough death in the history of our lineage to achieve the evolutionary change that we observe. Add sex, and this difficulty is resolved.

Recall that, in Haldane's improvement to our toy model, pushing a new mutation from a single copy to predominance and finally to fixation required 30 times as many "extra" or "useful" deaths as there were individuals in the population during a single generation. So that means the minimal number of useful deaths required to transform the chimp-human ancestor into a bona fide *Homo sapiens* would be 100,000 (that's the number of selected mutations) times 50,000 (that's the population size) times 30 (Haldane's factor). That gives us an answer of 150 billion useful deaths.

Hmmm. That's a really big number. How many deaths altogether, useful or not, were there along the lineage from the chimp-human ancestor to modern humans? Based on our estimate of the population size (which we just used), the average generation time (which we can make a pretty good guess at), and the total time since chimps and humans split (a number that comes from both archaeology and genetics), we can do another simple calculation to estimate the total number of deaths. I just worked it out, and it comes to ... 17.5 billion.

Oops. How can the number of useful or extra deaths that natural selection needs to evolve a human from its ancestor be larger than the total number of deaths that have taken place? Well, it can't. So what's the explanation?

In large part, it's sex. Say a certain man has a beneficial mutation. And say a certain woman has one of her own, only it's different: It confers a different advantage, and it's located somewhere else in the genome. And say, finally, this man and this woman get together and have kids. One of those kids might get both beneficial mutations, while another kid might get neither. When the doubly lucky kid survives and reproduces, while the doubly unlucky kid doesn't, a single death becomes doubly useful: It pays for the simultaneous rise in frequency of two beneficial mutations.

You can repeat the argument for parents who have two mutations, three, and so on. Thanks to sex, a single death can push many beneficial mutations toward their ultimate fixation. We can conclude, therefore, that although the price of life is death, sex improves the exchange rate.

LATER IN LIFE Darwin seems to have relinquished any notion that the theory of natural selection might redeem death and suffering, and thus vindicate a benevolent God. In fact, an epidemic appears to have played a pivotal role in shifting his views. What shattered his faith once and for all was watching his beloved little girl Annie suffer and die from scarlet fever and perhaps tuberculosis. After that, Darwin's views seem to have had less in common with Father Paneloux's than they did with those of Dr. Rieux, Camus' heroic narrator, who works tirelessly to stop the plague. Rieux vehemently rejects Paneloux's sermon. The scourge is a scourge, he argues, and there's no vindicating it.

And yet, though Darwin may have found no ultimate vindication for death in the creation of beautiful living things, he would continue to find profound joy in such beauty. In sexual selection, he discovered the origin of life's most extravagant displays. He attributed a great deal of importance to that process in the descent of *Homo sapiens* from hominid ancestors. To my knowledge, though, he never realized what Haldane and genomics have helped us to see here, that sex can greatly reduce the toll required for a certain measure of evolution. ☺

AARON HIRSH is a writer and biologist with strong interests in education, evolution, and the environment. His first book, *Telling Our Way to the Sea*, won a National Outdoor Book Award for Natural History Writing and was a finalist for the William Saroyan International Prize. He is now working on another book about the history and fate of our planet. Aaron is also currently board chair for Ecology Project International.

REFERENCES

1. Boyko, A.R., *et al.* Assessing the evolutionary impact of amino acid mutations in the human genome. *PLoS Genetics* **4**, e1000083 (2008).
2. Castillo-Davis, C.I. The evolution of noncoding DNA: How much junk, how much func? *Trends in Genetics* **21**, 533-536 (2005).
3. Chen, F.C. & Li, W.H. Genomic divergences between humans and other hominoids and the effective population size of the common ancestor of humans and chimpanzees. *American Journal of Human Genetics* **68**, 444-456 (2001).
4. The Chimpanzee Sequencing and Analysis Consortium. Initial sequence of the chimpanzee genome and comparison with the human genome. *Nature* **437**, 69-87 (2005).
5. Enard, D., Messer, P.W., & Petrov, D.A. Genome-wide signals of positive selection in human evolution. *Genome Research* **24**, 885-895 (2014).
6. Haldane, J.B.S. The cost of natural selection. *Journal of Genetics* **55**, 512-524 (1957).
7. Kohn, M.H. Rapid sequence divergence rates in the 5 prime regulator regions of young *Drosophila melanogaster* duplicate gene pairs. *Genetics and Molecular Biology* **31**, 575-584 (2008).
8. Langergraber, K.E., *et al.* Generation times in wild chimpanzees and gorillas suggest earlier divergence times in great ape and human evolution. *Proceedings of the National Academy of Sciences* **109**, 15716-15721 (2012).
9. Loehlin, D.W., Ames, J.R., Vaccaro, K., & Carroll, S.B. A major role for noncoding regulatory mutations in the evolution of enzyme activity. *Proceedings of the National Academy of Sciences* **116**, 12383-12389 (2019).
10. Peyregne, S., Boyle, M.J., Dannemann, M., & Prüfer, K. Detecting ancient positive selection in humans using extended lineage sorting. *Genome Research* **27**, 1563-1572 (2017).
11. Rands, C.M., Meader, S., Ponting, C.P., & Lunter, G. 8.2% of the human genome is constrained: Variation in rates of turnover across functional element classes in the human lineage. *PLoS Genetics* **10**, e1004525 (2014).
12. Tenesa, A., *et al.* Recent human effective population size estimated from linkage disequilibrium. *Genome Research* **17**, 520-526 (2007).

#THISISWHATASCIENTISTLOOKSLIKE™



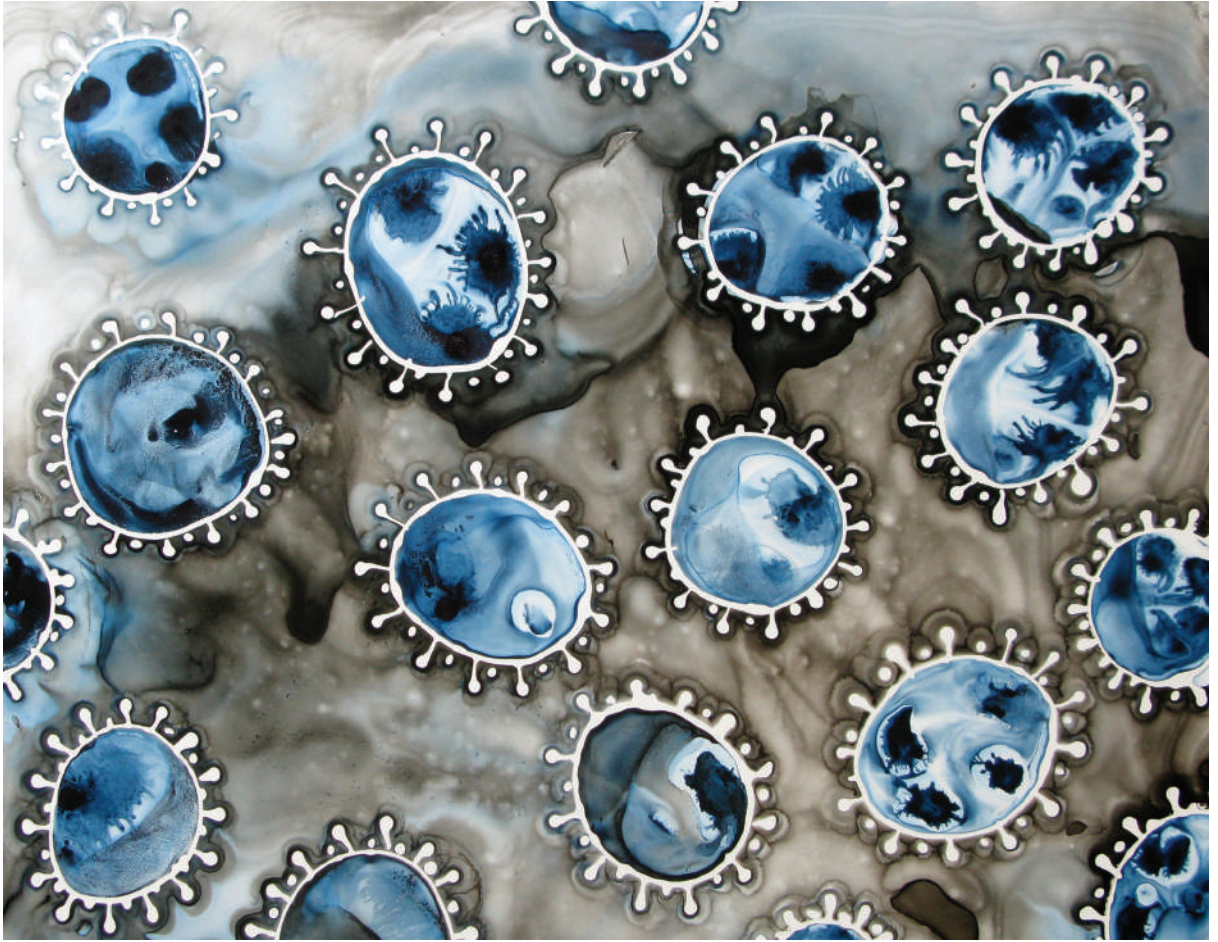
IF/THEN[®]

Collection



 @IFTHENSHECAN

IFTHENCOLLECTION.ORG



MICHELE BANKS, *Indigo Coronavirus*, 2020, ink on Yupo paper, 12 x 16 inches.

COVID-19

Creative Response Questionnaire

**Please share your projects,
your stories and your inspiration
during this difficult time**

Cultural Programs of the National Academy of Sciences has created a questionnaire to collect information about creative responses to the coronavirus pandemic. Collaboration and integrative ideas are critical now more than ever. Please help us collect information as we generate a time capsule of creative responses. Share your creative projects or add projects that have inspired you.

TO SUBMIT A CREATIVE RESPONSE, VISIT WWW.CPNAS.ORG.

   @CPNAS



**CULTURAL
PROGRAMS OF
THE NATIONAL
ACADEMY OF
SCIENCES**

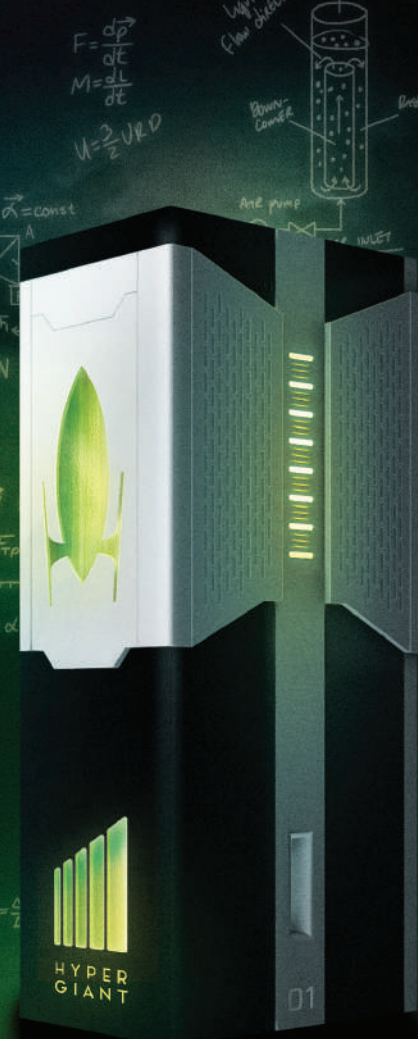
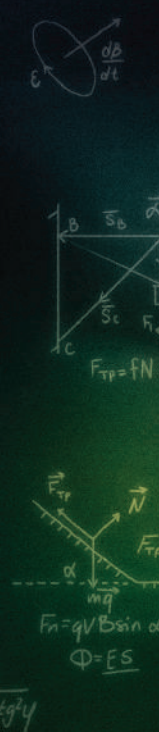
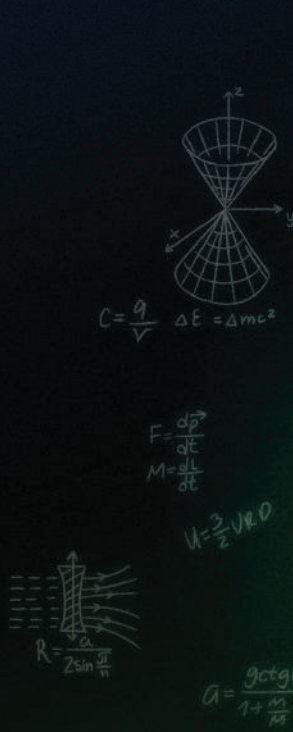
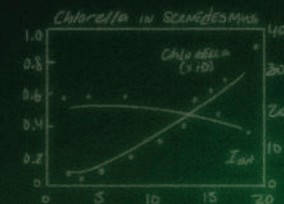
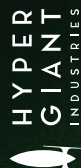
SCIENCE PROJECTS AREN'T JUST FOR KIDS.

Sometimes they can save the world. Like the EOS Bioreactor, developed by Hypergiant R&D Labs. Capable of inhaling and eliminating carbon at a rate 10 times more efficient than trees. Then converting it into carbon-rich lipids for biofuel. It's more than a small step. It's a Hypergiant leap.

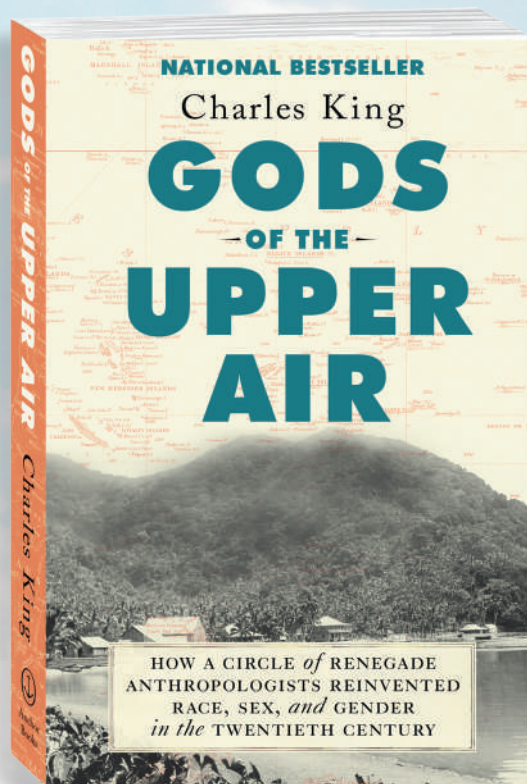
Find out what else the world's been missing at HYPERGIANT.COM

EOS
BIOREACTOR

HYPERGIANT_INDUSTRIES_RESEARCH_AND_DEVELOPMENT_LABS



How a Circle of Renegade Anthropologists —Franz Boas, Margaret Mead, Ruth Benedict, Ella Deloria, and Zora Neale Hurston— Reinvented Race, Sex, and Gender in the Twentieth Century



“Captivating.” —NPR

“The lives of Boas and his students make for riveting storytelling, and the author’s imaginative prose enlivens their discoveries, romantic exploits and professional jealousies.”

—*The Washington Post*

“Elegant and kaleidoscopic. . . . Boas and his circle confronted a bigotry that was scientifically endorsed at the time, and they dismantled it.”

—*The New York Times*

WINNER

The Anisfield-Wolf Book Award
The Francis Parkman Prize

FINALIST

National Book Critics Circle Award
Los Angeles Times Book Prize
The Plutarch Award

Available wherever books are sold



AnchorBooks.com



[@charleskingdc](https://twitter.com/charleskingdc)

www.charleskingauthor.com

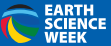
Celebrate Earth Science Week!

October 11-17, 2020



Join in the international celebration of Earth science that reaches millions of educators, students, and others every year. This year's event focuses on the theme of "Earth Materials in Our Lives."

- Classroom Activities and Lessons
- Outdoor Learning Activities
- Videos, News, and Planning Tips
- Teaching and Learning Resources
- Art, Essay, Photo, and Video Contests
- Social Media Links
- Geoscience Career Resources
- Local Event Listings
- Spanish-Language Materials



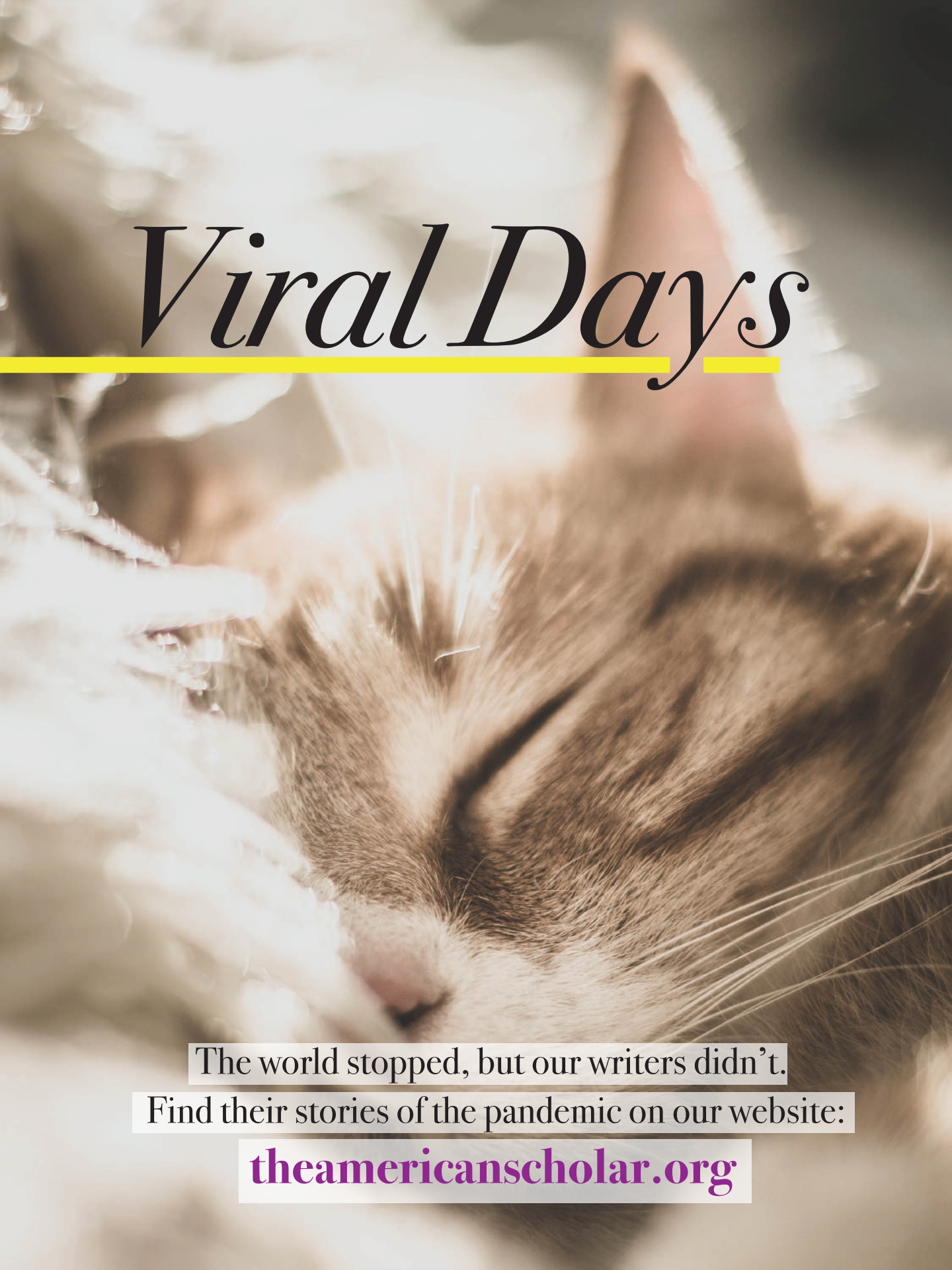
Earth Materials in Our Lives



EARTH SCIENCE WEEK  www.earthsciweek.org

2020 Earth Science Week poster by AGI/Brenna Tobler; Earth Images: AGI/K. Cantner; Galaxy Image: Miriam Espacio from Pexels

Find all this and more at www.earthsciweek.org



Viral Days

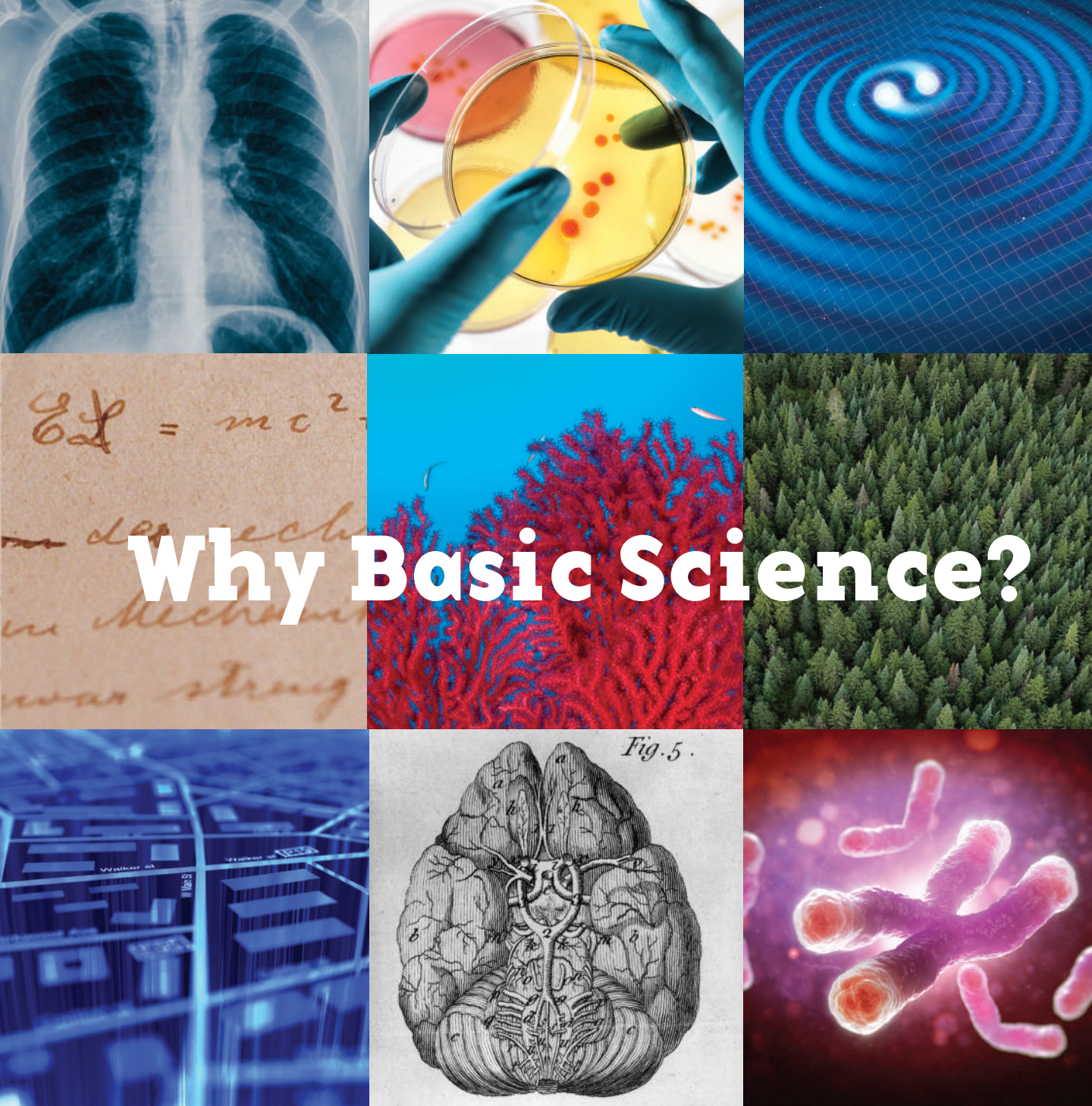
The world stopped, but our writers didn't.
Find their stories of the pandemic on our website:

theamericanscholar.org

■ Discovering Our Universe Together

nationalastro.org





Why Basic Science?



SCIENCE

PHILANTHROPY ALLIANCE

Advancing basic science—The foundation of our future

www.sciphil.org



NAUTILUS OCEANS

"Every time I slip into the ocean, it's like going home."

Sylvia Earle

Working with global ocean research and conservation organizations, *Nautilus* is exploring ocean science and culture

nautilus.us



www.fondation-bertarelli.org



THE 13TH ANNUAL
IMAGINE SCIENCE
FILM FESTIVAL

MIGRATION

NEW YORK
OCTOBER 16-23

Issue Index



33

2020
88 LOVE & SEX
89 THE DARK SIDE



32

2020
85 REOPENING
86 ENERGY
87 RISK



31

2020
83 INTELLIGENCE
84 OUTBREAK



30

2020
80 ALIENS
81 MAPS
82 PANPSYCHISM



29

2020
77 UNDERWORLDS
78 ATMOSPHERES
79 CATALYSTS



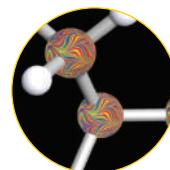
28

2019
75 STORY
76 LANGUAGE



27

2019
72 QUANDARY
73 PLAY
74 NETWORKS



26

2019
68 CONTEXT
69 PATTERNS
70 VARIABLES
71 FLOW



25

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



24

2018
56 PERSPECTIVE
57 COMMUNITIES
58 SELF



23

NOV/DEC 2017
54 THE UNSPOKEN
55 TRUST



22

SEPT/OCT 2017
52 THE HIVE
53 MONSTERS



21

JULY/AUG 2017
50 EMERGENCE
51 LIMITS



20

MAY/JUNE 2017
48 CHAOS
49 THE ABSURD



19

MAR/APR 2017
46 BALANCE
47 CONSCIOUSNESS

Science Connected.

Visit shop.nautil.us for single issues, subscriptions, and more.



18

JAN/FEB 2017

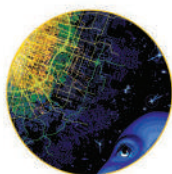
44 LUCK
45 POWER



17

NOV/DEC 2016

42 FAKES
43 HEROES



16

SEP/OCT 2016

40 LEARNING
41 SELECTION



15

JULY/AUG 2016

38 NOISE
39 SPORT



14

MAY/JUNE 2016

36 AGING
37 CURRENTS



13

MAR/APR 2016

34 ADAPTATION
35 BOUNDARIES



12

JAN/FEB 2016

32 SPACE
33 ATTRACTION



11

NOV/DEC 2015

30 IDENTITY
31 STRESS



10

SEP/OCT 2015

28 2050
29 SCALING



09

JULY/AUG 2015

25 WATER
26 COLOR
27 DARK MATTER



08

MAY/JUNE 2015

22 SLOW
23 DOMINOES
24 ERROR



07

MAR/APR 2015

19 ILLUSIONS
20 CREATIVITY
21 INFORMATION



06

WINTER 2015

16 NOTHINGNESS
17 BIG BANGS
18 GENIUS



05

FALL 2014

13 SYMMETRY
14 MUTATION
15 TURBULENCE



04

SUMMER 2014

10 MERGERS &
ACQUISITIONS
11 LIGHT
12 FEEDBACK



03

SPRING 2014

07 WASTE
08 HOME
09 TIME



02

WINTER 2014

04 THE UNLIKELY
05 FAME
06 SECRET CODES



01

FALL 2013

01 HUMAN UNIQUENESS
02 UNCERTAINTY
03 IN TRANSIT

SUBSCRIPTIONS

Address subscription and address changes to:
Nautilus
25 Broadway, 9th Floor
New York, NY 10004;
email: order@nautilus.us

Visit shop.nautilus.us for more information.

POSTMASTER

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

© 2020 NautilusNext, Inc.
All rights reserved

Joe Pettit

The engineer on what it takes to live and work in Antarctica

INTERVIEW BY MARISSA GRUNES

FEEL AT HOME

I first went down to Antarctica in 1990. The day I got there just happened to be my 30th birthday. It was almost a white-out. As we came off the plane, people would grab our hand and put it on the shoulder of the person in front of us and say, “Just hang onto this guy and follow them over to the vehicle.” I thought “Yeah, this is it!”

FOLLOW THE STARS

To spend an entire year is the only way to experience Antarctica. It changes every day—the light, the people, their moods, the pace of life. It’s amazing to use the stars spinning overhead during the winter as a sundial, where by the position of stars you know what time of day or night it is. It’s been 30 years for me now, which is hard to imagine. But every year there will be something that happens, or something I see, and I’ll be like, “Yeah, this is why I keep coming back, this is where the magic is.” For me it’s just the majestic nature of the place, the fact it’s so remote, so austere, and yet so incredibly beautiful.

HAVE NO EXPECTATIONS

You have to know what your expectations are. If you expect it to be hard, it’s going to be hard. If you expect it to be amazing and filled with new and interesting experiences, you end up looking for those experiences. A big danger is putting a departure date on the calendar. Inevitably you don’t make it out that day because the air strip needs to be adjusted or the plane can’t fly because the weather makes it impossible for the pilot to see

anything. A lot of people really suffer with that. They lose it. But people who can make plans A, B, C, and D and not be bothered by the fact that the first three plans just went out the window do well. The flexible are the ones who do best in Antarctica.

BE OPTIMISTIC

If you surround yourself with people who are optimistic, as well as ingenious and curious, then you’ve got a really good team. If you’ve got a bunch of pessimists together, then nothing is going to happen other than misery. That’s a fact of life anywhere, but when you’re really on the margins, and things can go either way depending on which decision you make, coming at problems optimistically broadens the horizon of possible ideas you can come up with, as opposed to, “Oh, it’s just not going to work.”

APPRECIATE LUCK

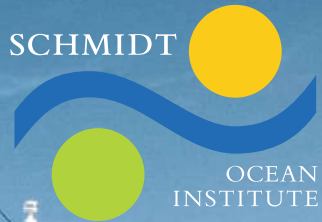
Once one of our supply crews was lost. The wind speed was so high it was roaring like a freight train. You had to get up to someone’s ear and yell at them to get any information past that roar. The wind then

went from 100 sustained knots to virtually zero. It just stopped all at once, and there was this fine haze of snow coming down. We called the supply van—“You guys have a flashlight?” We told them to get up on top of the van and start spinning around in a circle. Sure enough, somebody spotted a light and we got a compass bearing on them. It was a lucky break. Sometimes you just have to rely on that luck and say, “You know, that’s good enough.” ☺



COURTESY OF JOE PETTIT

SCHMIDT



OCEAN
INSTITUTE



**OUR PLANET'S
OCEAN UNDERSTOOD
THROUGH
TECHNOLOGICAL
ADVANCEMENT,
INTELLIGENT
OBSERVATION,
AND OPEN SHARING
OF INFORMATION**

**JOIN US FOR OUR
#OZOCEANS2020
CAMPAIGN**

as we live stream
never-before seen
environments in
Australia's deep waters

schmidtocean.org



BALENCIAGA