

SPECIAL ISSUE : SEX AND GENDER

SCIENTIFIC AMERICAN

It's Not a Women's Issue

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a stake in the
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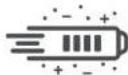
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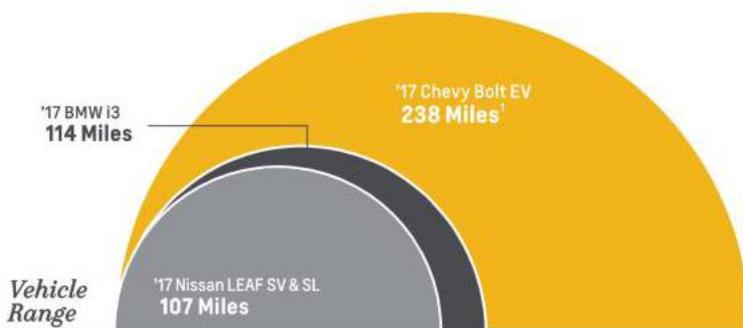


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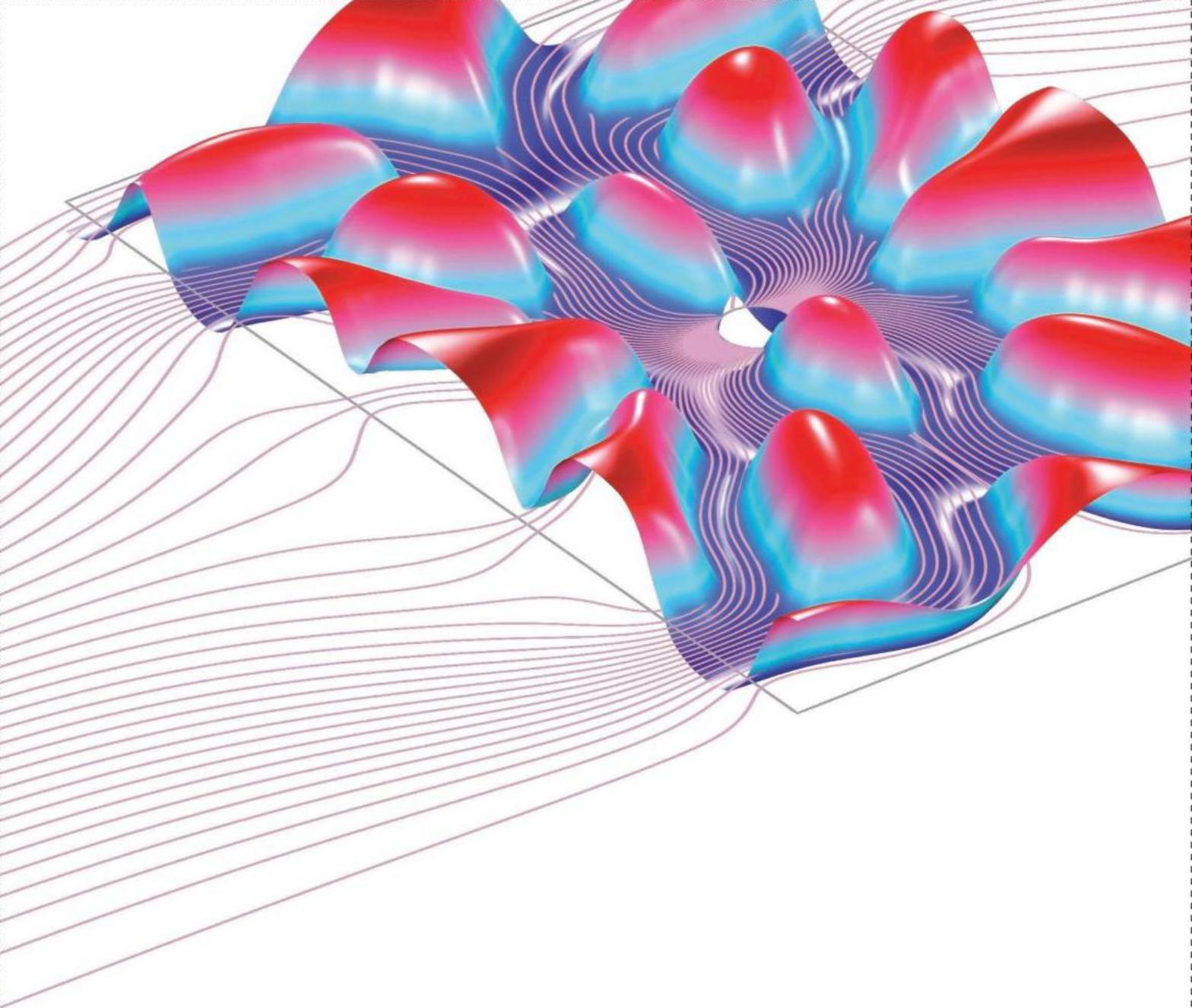
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Stroke Rates among U.S. Millennials

Scientific American analyzes why strokes among women and men ages 18 to 34 have soared in recent years.

Go to www.ScientificAmerican.com/sep2017/stroke-research

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Mariette DiChristina is editor in chief of *Scientific American*. Follow her on Twitter @mdichristina

Welcome to Everybody's Issue

“How will *Scientific American* be different with you as its first woman editor in chief?”

It was December 2009, and the official announcement had just gone out about my taking the helm of a magazine founded in 1845. I suppose I should have expected the reporter's question. But instead I was surprised. Irritable thoughts swirled unbidden: “Why is being a woman in leadership still considered an amazing thing? I mean, how was the magazine different when I was its first female executive editor for eight years?” I just wanted to be thought of as capable, I realized, not capable, *for a woman*. Other reporters followed similar themes.

The questions stayed with me on the commute home. Did people think I would tint all the pages pink? Start running fashion on the Web site? Create a recipes app?

That evening, as usual, I had dinner with my husband and

two girls, then 12 and 8. We talked about our days at school and work. I mentioned the interviews and that I was surprised by the questions. I asked the girls, “Why do you think people are making such a big deal about this?” I'll never forget the

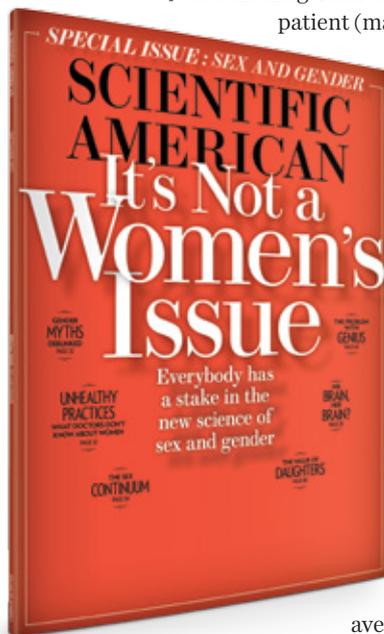
patient (maybe even long suffering?) response from my older daughter, Selina: “Well, Mommy, *of course* people want someone they can look up to.” Mallory nodded, “Yes, Mom, that's right!”

Well, of course. The children saw plainly what I had not. And until that moment, I had been thinking about things in exactly the wrong way, too: it was time to appreciate the opportunity that I had to help. At *Scientific American*, we haven't been perfect about that, I have to admit, but we're trying to get better. The staff is about half women, for instance. About half of our large (more than eight million a month total) online audience is women. When we looked (after a story count showed a skewed authorship ratio in print features), we found that we have about a 50–50 male-female overall

average for writers over the course of a year. We

know we need to do more, and we welcome your ideas.

Because, as this special edition demonstrates, “it's not a woman's issue” to create the best, inclusive future for us all. It's everybody's issue. (Thanks, girls.) ■



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May 2017

THE FOX AND THE HOUND

“How to Build a Dog,” by Lyudmila Trut and Lee Alan Dugatkin, describes a decades-long experiment in Siberia in which foxes were selectively bred for tameness, resulting in physical traits we associate with dogs. Turning a fox into a dog certainly offers insight into how our ancestors tamed other animals. But maybe it also tells us something about how we tamed ourselves, changing from apes to modern humans.

The authors describe juvenile facial characteristics as a component of the so-called domestication syndrome, and it does distinguish us from our closest living relatives, chimpanzees and bonobos. Further, docility is certainly necessary for large groups of humans to cooperate in urban environments, even if it also predisposes us to “follow the leader,” for good or for ill.

Fifty generations of foxes could be bred in a single person’s lifetime, whereas 50 generations of humankind still take us back only 1,500 years. How much have we been domesticating ourselves in the 10,000 years since agriculture and the first cities? Culture may be capable of driving biology faster than we realize.

PHILIP EARLY *Bainbridge Island, Wash.*

The article on making a dog from a fox reminded me of the history of the greyhound, where, in the opposite direction,

“Vastly increased political influence is necessary to turn the president, Congress or state legislators away from policies that ‘toss accepted science out the window,’ and that requires a full-scale social movement.”

DAVID JOHNS *PORTLAND STATE UNIVERSITY*

many traits from the wild were accentuated in a domesticated animal through the process of breeding.

When I adopted a retired racing greyhound, a little research showed how breeding purely for speed had led to many anatomical similarities with cheetahs. (For example, both have long legs and a long body and neck and a deep chest.) As with the doglike foxes in the article, unnatural selection greatly sped up this “evolution.” Greyhounds remain dogs at heart, though. They take retirement seriously: we call them 45-mile-per-hour couch potatoes.

TOM WRIGHT *San Diego*

POLITICAL SCIENCE

Thank you for “A March for Science Is Not Enough” [Science Agenda], the editors’ column on the need for scientists to do more than march to turn the president, Congress or state legislators away from “policies likely to increase pollution, harm health, reduce our ability to forecast natural hazards ... and toss accepted science out the window.”

Vastly increased political influence is necessary, and that requires a full-scale social movement that can not only lobby but keep the pressure on with a range of activities that make business as usual impossible. We are ignoring a wheel that has been invented. Only such movements—which brought about the fall of apartheid and segregation—can beat powerful in-

terests. Movement-building requires grassroots organizing, which extends far beyond the scientific community, as the editorial notes. Unfortunately, those concerned with the health of the earth and its creatures pivoted from grassroots organizing in the 1970s and opted for big nongovernmental organizations that depended on check writers and played an exclusively insider game. We have lost political influence since then. Check writers don’t change the world. They lack the passion and commitment of activists.

Part of the problem may also be that most of us are middle class. We have too much vested in the status quo. We have careers. We really don’t want to take on population, consumption or those with great power. We don’t want to stand the world on its head. It’s risky.

As a veteran of the movements for U.S. civil rights, against the Vietnam War and against South African apartheid, among others, I believe that until we are willing to organize, we aren’t going to make much of a difference.

DAVID JOHNS *Hatfield School of Government, Portland State University*

GENE FITTING

In “Missing Links,” Philip L. Reno describes finding stretches of DNA that have long been present in various mammals but that had been turned “off.” Then the ancestors of we humans came along, and the “off” switches—stretches of non-coding DNA—were removed, which allowed certain proteins to be produced that gave us traits that make us a unique species. This seems to cause a problem for the currently accepted Darwinian method of evolution.

Apparently one of the affected genes, when turned on, allowed the brain to grow larger by not pruning neurons. Charles Darwin proposed that species’ traits were created, by random mutation, at the time they were “needed” (that is, genes that aided in survival endured as soon as they appeared). Yet this case seems to require that a gene be provided long before it was needed, along with the necessary machinery to keep it inactive. It seems impossible that such a mechanism could be created by random processes that would work perfectly mil-

lions of years after it was made. Inactive DNA is supposed to be removed, as eyeless animals that live in caves attest. Do I misunderstand the process?

CARL COX *Mansfield, Mo.*

RENO REPLIES: I would like to correct Cox on a few crucial areas. The stretches of DNA that humans lost were not “off” switches but “on” switches, key regulatory sequences for genes. Our hypothesis is that when certain genes were turned off, or expressed to a lesser degree, this limited the number of neurons pruned and allowed for a larger brain. The genes and their switches were not developed before they were needed but rather were active in many mammals, including our ancestors. We propose that humans had turned them off via DNA deletion. This is perfectly in line with Darwinian theory. Random deletions occur as a form of mutation all the time (on an evolutionary timescale). Usually deletions will have no effect or be detrimental.

Yet sometimes the loss of key regulatory sequences can alter gene expression in ways that produce beneficial changes in animals, including humans. And although a cave fish may evolve eyelessness because of the costs associated with developing and maintaining an organ that provides no benefit, there seems to be little cost to keeping around a few extra billion base pairs of DNA in our genome.

CLARIFICATION

In Lee Billings's review of *Apollo 8: The Thrilling Story of the First Mission to the Moon*, by Jeffrey Kluger [Recommended], the flight of the *Apollo 8* astronauts was described as the first time humans escaped Earth's gravity. Technically, *Apollo 8* did not reach a sufficiently high velocity to break free of Earth's gravitational field, although its crew members were the first humans to leave the planet's orbit.

ERRATUM

In “Schizophrenia's Unyielding Mysteries,” by Michael Balter, the box entitled “Research Dragnet Falls Short” incorrectly referred to there being 23 chromosomes in the human nucleus. There are 23 pairs of chromosomes, or 46 in all.

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End the Assault on Women's Health

Republican efforts to dismantle U.S. health care unfairly target one gender

By the Editors

There's something rotten in the state of women's health. As this article is being written in July, Republicans in Congress are engaged in a frenzied effort to repeal and replace the Affordable Care Act (ACA) put in place by the Obama administration. At least 22 million Americans would lose medical insurance by 2026 under the latest version of this plan—which includes large cuts to Medicaid—and lack of insurance means more sickness and death for thousands, data show. These cuts threaten to affect women more than men—whether by removing basic health coverage, cutting maternity care or sharply limiting reproductive rights.

It's time to take a stand against this war on women's health.

Current events are just the latest insult in a long history of male-centric medicine, often driven not by politicians but by scientists and physicians. Before the National Institutes of Health Revitalization Act of 1993, which required the inclusion of women and minorities in final-stage medication and therapy trials, women were actively excluded from such tests because scientists worried that female hormonal cycles would interfere with the results. The omission meant women did not know how drugs would affect them. They respond differently to illness and medication than men do, and even today those differences are inadequately understood. Women report more intense pain than men in almost every category of disease, and we do not know why. Heart disease is the num-

ber-one killer of women in the U. S., yet only a third of clinical trial subjects in cardiovascular research are female—and fewer than a third of trials that include women report results by sex.

The Republican assault on health care will just make things worse. The proposed legislation includes provisions that would let states eliminate services known as “essential health benefits,” which include maternity care. Before the ACA made coverage mandatory, eight out of 10 insurance plans for individuals and small businesses did not cover such care. The proposed cuts would have little effect on reducing insurance premiums, and the cost would be shifted to women and their families—who would have to take out private insurance or go on Medicaid (which the proposed bill greatly limits)—or to hospitals, which are required by law to provide maternity care to uninsured mothers.

The bill, in its current form, would also effectively block funding for Planned Parenthood, which provides reproductive health services to 2.4 million women and men. The clinics are already banned from using federal funding for abortions except in cases of rape or incest or when the mother's life is in danger, in accordance with the federal Hyde Amendment. So the Planned Parenthood cuts would primarily affect routine health services such as gynecological exams, cancer screenings, STD testing and contraception—and these clinics are sometimes the only source for such care. Regardless of which side you are on in the pro-life/pro-choice debate, these attempts to remove access to such basic services should alarm us all.

The Trump administration also has been chipping away at the ACA's birth-control mandate. A proposed regulation leaked in May suggested the White House was working to create an exemption to allow almost any employer to opt out of covering contraception on religious or moral grounds. Nationwide, women are increasingly turning to highly effective long-acting reversible contraceptives (LARCs) such as intrauterine devices (IUDs). The percentage of women aged 15 to 44 using LARCs increased nearly fivefold from 2002 to 2013. Decreased coverage for contraceptives translates to less widespread use and will likely mean more unintended pregnancies and abortions.

And abortions will become harder to obtain. After *Roe v. Wade*, many states tried to put in place laws to hamstring abortion clinics. These efforts have only ramped up in recent years, as many states have enacted so-called TRAP laws (short for targeted regulation of abortion providers), unnecessarily burdensome regulations that make it very difficult for these clinics to operate. Recognizing this fact, the Supreme Court struck down some of these laws in Texas in 2016, but many are still in place in other states. Rather than making women safer, as proponents claim, these restrictions interfere with their Supreme Court-affirmed right to safely terminate a pregnancy.

Whether or not the repeal-and-replace legislation passes this year, these attacks are part of a larger war on women's health that is not likely to abate anytime soon. We must resist this assault. Never mind “America First”—it's time to put women first. ■

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Carl Manlan is an Ivorian economist, chief operating officer at the Ecobank Foundation and a 2016 New Voices Fellow at the Aspen Institute. The views and opinions in this article are his own.



Africa's CDC Can End Malaria

But the body modeled after
the U.S. agency needs funding

By Carl Manlan

More than 65 years ago Americans found a way to ensure that no one would have to die from malaria ever again. The disease was eliminated in the U.S. in 1951, thanks to strategies created through the Office of Malaria Control in War Areas, formed in 1942, and the Communicable Disease Center (now the U.S. Centers for Disease Control and Prevention), founded in 1946.

The idea for Africa's own Centers for Disease Control and Prevention (Africa CDC) was devised in 2013 and formalized after the worst Ebola outbreak in history the following year. The Africa CDC, which was officially launched in January of this year, is a growing partnership that aims to build countries' capacity to help create a world that is safe and secure from infectious disease threats.

Just as Americans made the formation of their CDC a priority, Africans have a responsibility to ensure the funding and development of our CDC to keep diseases from further altering the course of our socioeconomic transformation. Ebola is terrifying to many people, but malaria is a more devastating illness: the latest World Health Organization statistics show that more than 400,000 people died from the disease in 2015, and 92 percent of those deaths occurred in sub-Saharan Africa. Further, six countries in Africa account for 47 percent of all global malaria cases.

Based on my years of working for organizations such as the Global Fund to Fight AIDS, Tuberculosis and Malaria, the United

Nations Development Program, the U.N. Economic Commission for Africa and the Africa Against Ebola Solidarity Trust, I see three priorities that are needed to make a major impact on ending malaria:

First, we must strengthen and build mechanisms to gather real-time data from communities across Africa for informed decision making. The expansion of mobile phones is an important method for achieving this because they can connect people and their health data for targeted interventions to prevent and arrest outbreaks. The Africa CDC and its five Regional Collaborating Centers must lead the transition that would ensure consistent data collection, dissemination and interpretation.

Second, we must make new resources available to support the Africa CDC. Ebola's economic cost to Sierra Leone, Guinea and Liberia, the focus of the outbreak, was up to \$4 billion. The African private sector raised \$34 million to end Ebola for good. This momentum needs to continue for an African-funded

CDC. Some African countries and similar health organizations across the world have provided initial resources for the Africa CDC to launch, but it is not enough. Africans have a responsibility to fund another \$34 million over the next two years to make Africa safer and stronger for economic growth.

Third, we must invest in other ways to end malaria. The private sector and the middle class it creates are the key to ending the disease for good. We will not achieve that without universal health coverage through a fully funded and operational Africa CDC.

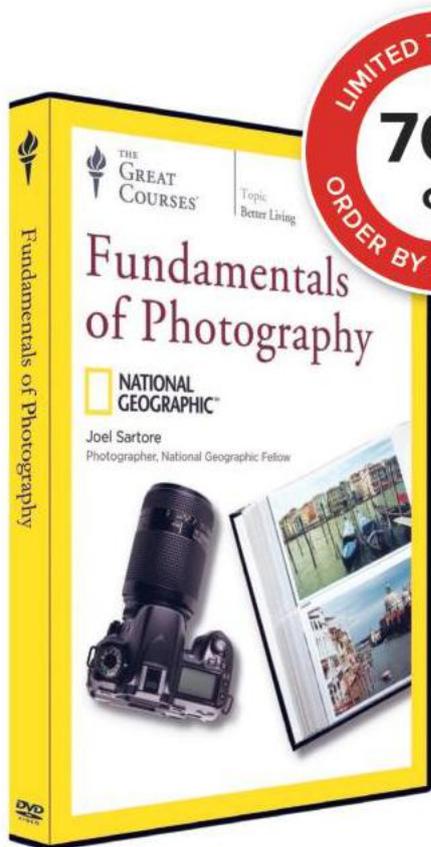
There are already positive signs that recent increases in resources, political determination and communities' commitments are leading to the possibility of malaria's elimination and, ultimately, its eradication. In Senegal, for example, now only 3.3 percent of outpatient visits are malaria-related, down from 36 percent more than 15 years ago. While the transformation is impressive, full elimination in Senegal and other countries cannot be achieved without regional and continental efforts supported by stronger data and evidence.

Malaria and other preventable diseases continue to challenge our ability to transform our economies at the pace required to support our population growth. Ultimately, for Africa to achieve malaria eradication, it is necessary to translate the Africa CDC's mandate from the African Union into a funded mechanism to inform health investment.

Ending malaria was the impetus that led to a strong and reliable CDC in the U.S., and now Africa has an opportunity to repeat that success—ideally by 2030, when the world gathers to assess progress toward achieving the U.N.'s Sustainable Development Goals. We have the opportunity to save many, many lives through the Africa CDC. Let's make it happen. ■

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ADVANCES



Researchers excavate remains of early humans at Jebel Irhoud in Morocco. Inset shows a composite skull reconstruction. For more on these discoveries, go to www.ScientificAmerican.com/irhoud

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HUMAN ORIGINS

The Oldest *Homo sapiens*?

Fossils from Morocco complicate the story of modern humans

The year was 1961. A barite mining operation at the Jebel Irhoud massif in Morocco, some 100 kilometers west of Marrakech, turned up a fossil human skull. Subsequent excavation uncovered more bones from other individuals, along with animal remains and stone tools. Originally thought to be 40,000-year-old Neandertals, the fossils were later reclassified as *Homo sapiens*—and eventually redated to roughly 160,000 years ago. Still, the Jebel Irhoud fossils remained something of a mystery because in some respects they looked more primitive than older *H. sapiens* fossils.

Now new evidence is rewriting the Jebel Irhoud story again. A team led by Jean-Jacques Hublin of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany, has recovered more human fossils and stone tools, along with compelling evidence that the site is far older than the revised estimate. The researchers described their findings recently in *Nature*. If the fossils do in fact represent *H. sapiens*, as the team argues, the finds push back the origin of our species by more than 100,000 years and challenge leading ideas about where and how our lineage evolved. But other scientists disagree over exactly what the new findings mean. Far from tidily solving the puzzle of our origins, the Jebel Irhoud discoveries add to mounting evidence that the dawning of our kind was a very complicated business.



COURTESY OF SHANNON McPHERSON/Max Planck Institute for Evolutionary Anthropology (landscape); COURTESY OF PHILIPP QUINZ/Max Planck Institute for Evolutionary Anthropology (skulls)

Experts have long agreed that *H. sapiens* got its start in Africa. Up to this point, the oldest commonly accepted traces of our species were 195,000-year-old remains from the site of Omo Kibish and 160,000-year-old fossils from Herto, both in Ethiopia. Yet DNA evidence and some enigmatic fossils hinted that our species might have deeper roots.

In their recent work, Hublin and his colleagues unearthed fossils of several other individuals from a part of the Jebel Irhoud site that the miners left undisturbed. The team's finds include skull and lower jaw bones, as well as stone tools and the remains of animals the humans hunted. Multiple techniques date the rock layer containing the fossils and artifacts to between 350,000 and 280,000 years ago.

The researchers found that the sizes and shapes of the Jebel Irhoud face, lower jaw and teeth align with those of *H. sapiens*, not Neandertals or other archaic humans. But the braincase is elongated like that of archaic humans, not rounded like that of their modern counterparts. Such variations are associated with differences in brain organization. The team concluded that the Jebel Irhoud remains represent "the very root of our species, the oldest *H. sapiens* ever found in Africa or elsewhere," Hublin said at a press conference. The remains

reveal a group that lacked some of our hallmark traits but whose anatomical form could have gradually evolved into our modern one, he and his colleagues report in their paper describing the fossils.

Hublin noted that the findings do not imply that Morocco was the cradle of modern humankind. Instead, taken together with other fossil discoveries, they suggest that the emergence of *H. sapiens* was a pan-African affair. By 300,000 years ago early *H. sapiens* had spread across the continent. This dispersal was helped by the fact that Africa was quite different back then—the Sahara was green, not the forbidding desert barrier that it is today.

Not all scientists accept the premise that the Jebel Irhoud fossils belong to *H. sapiens*, however. Paleoanthropologist John Hawks of the University of Wisconsin–Madison notes that Hublin and his colleagues did not compare the Jebel Irhoud remains with 800,000-year-old fossils found in Spain from a species called *Homo antecessor*: "Maybe Jebel Irhoud was evolving into modern humans, but another possibility is that it is retaining facial morphology from an *H. antecessor*-like population that may have been the last common ancestor of Neandertals and later African archaic humans."

The new fossils "raise major questions

about what features define our species," observes paleoanthropologist Marta Mirazón Lahr of the University of Cambridge. "[Is] it the globular skull, with its implications [for] brain reorganization, that makes a fossil *H. sapiens*? If so, the Irhoud population [represents] our close cousins" rather than members of our species. But if, on the other hand, a small face and the shape of the lower jaw are the key traits, then the Jebel Irhoud remains could be from our actual ancestors—and thus shift the focus of scientists who study modern human origins from sub-Saharan Africa to the Mediterranean—Mirazón Lahr says.

Either way, the discoveries could fan debate over who invented the artifacts of Africa's Middle Stone Age cultural period, which spanned the time between roughly 300,000 and 40,000 years ago. If *H. sapiens* was around 300,000 years ago, it could be a contender. But other human species were on the scene back then, too, including *Homo heidelbergensis* and *Homo naledi*.

The Jebel Irhoud finds "make the picture nicely complicated," says archaeologist Christian Tryon of Harvard University. But the added wrinkle means that the scientists chasing the origins of our own species have their work cut out for them. Sometimes the most familiar things are also the most mysterious. —Kate Wong

MATERIALS SCIENCE

A Moth's Eye

Insect orbs inspire a glare-free coating for cell-phone screens

It is a summer night, and the moths are all aflutter. Despite being drenched in moonlight, their eyes do not reflect it—and soon the same principle could help you see your cell-phone screen in bright sunlight.

Developing low-reflectivity surfaces for electronic displays has been an area of intensive research. So-called transflective liquid-crystal displays reduce glare by accounting for both backlighting and ambient illumination. Another approach, called adaptive brightening control, uses sensors to boost the screen's light. But both technologies guzzle batteries, and neither is completely effective. The anat-



omy of the moth eye presents a far more elegant solution, according to Shin-Tson Wu of the University of Central Florida, who described a technique for making an insect-inspired display coating recently in *Optica*.

When light moves from one medium to another, it bends and changes speed as the result of differences in a material property called refractive index. If the difference is sharp—as when light moving through air suddenly hits a pane of glass—much of the

light is reflected. But a moth's eye is coated with tiny, uniform bumps that gradually bend (or refract) incoming light. The light waves interfere with one another and cancel one another out, rendering the eyes dark.

Wu and his colleagues at National Taiwan University created a silicon dioxide mold that resembles a moth's eye surface and used it to produce a hard, dimpled coating on a flexible sheet. Although these dimples are concave rather than convex such as those on the moth's eye, they prevent glare in the same way. In tests, the material resulted in less than 1 percent reflectance.

"The main barrier to the wide-scale adoption of this approach is its cost," says Stuart Boden, who researches semiconductor device fabrication at the University of Southampton in England and who was not involved in the new work. Wu is hoping to find a commercial partner to scale up the technology. —Morgen Peck

NANOSCIENCE

Skinlike Sunscreen

A synthetic form of melanin could protect cells from the sun's harmful rays

In the heat of summer, many people feel a need to slather on more sunscreen to prevent the sun's ultraviolet radiation from crisping their skin. But scientists may have found a new way to block these dangerous rays: melanin-imitating nanoparticles that protect skin cells from within. If proved, this approach could be used to develop better topical protection and possibly treatments for certain skin disorders as well.

The darkening pigment melanin is one of the body's primary natural defenses against UV-induced DNA damage. Below the skin's surface, special cells secrete melanosomes, which produce, store and transport melanin. These structures are absorbed

Illustrations by Thomas Fuchs



by skin cells called keratinocytes and form protective, UV-blocking shells around the cells' nuclei. People suffering from diseases such as albinism and vitiligo, however, have faulty melanin production and are highly susceptible to the effects of UV.

To create synthetic versions of these melanosomes, researchers at the University of California, San Diego, bathed dopamine—a signaling chemical found in the brain and other parts of the body—in an alkaline solution. This step produced melaninlike nanoparticles with shells and cores made of polydopamine, a dopamine-based polymer. When incubated in a petri dish with human keratinocytes, the synthetic particles were absorbed by the skin cells and distributed

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around their nuclei like natural melanin.

The cells “are able to process [the synthetic nanoparticle] and then convert it into a sort of cap over the nucleus,” says study author Nathan Gianneschi, a biochemist now at Northwestern University. Like melanin, the synthetic material also functions as a pigment to darken skin, but “it wasn't that it just filled the cells and made them darker,” he says. “It actually structured them.”

Not only were the melaninlike nanoparticles transported and distributed throughout skin cells like natural melanin—they also protected the cells' DNA. The researchers incubated skin cells with nanoparticles and then exposed them to UV radiation for three days. Fifty percent of the skin cells that absorbed the nanoparticles survived, compared with just 10 percent of those without nanoparticles. The findings were published earlier this year in *ACS Central Science*.

Now that the team knows the melaninlike nanoparticles are treated the same as natural melanin and effectively protect cells, the next step will be determining the absorption mechanism. —Matthew Sedacca

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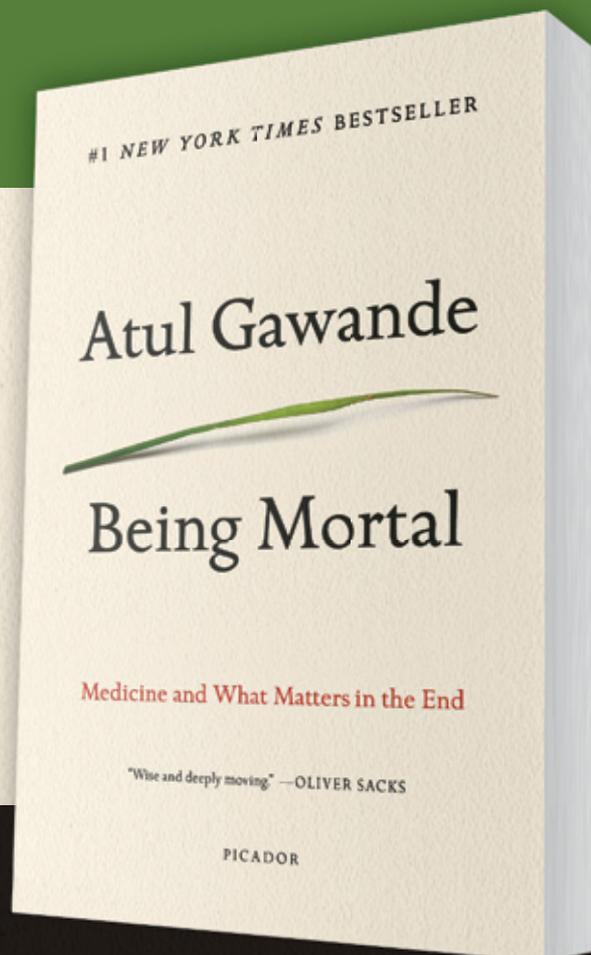
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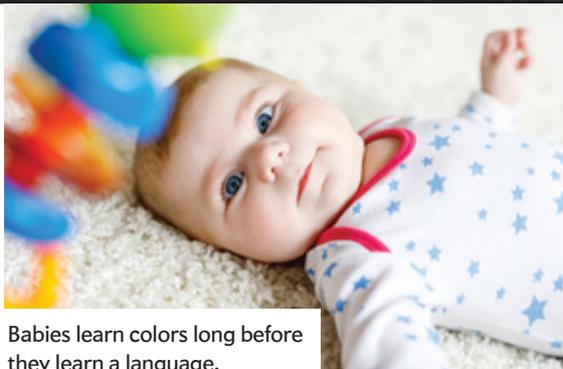
NEUROSCIENCE

Baby's Rainbow

Biology plays a stronger role in color perception than once believed

In English the sky is blue, and the grass is green. But in Vietnamese there is just one color category for both sky and grass: *xanh*. For decades cognitive scientists have pointed to such examples as evidence that language largely determines how we see color. But new research with four- to six-month-old infants indicates that long before we learn language, we see up to five basic categories of hue—a finding that suggests a stronger biological component to color perception than previously thought.

The study, published recently in the *Proceedings of the National Academy of Sciences USA*, tested the color-discrimination abilities of more than 170 British infants. Researchers at the University of Sussex in England measured how long babies spent



Babies learn colors long before they learn a language.

gazing at color swatches, a metric known as looking time. First the team showed infants one swatch repeatedly until their looking time decreased—a sign they had grown bored with it. Then the researchers showed them a different swatch and noted their reaction. Longer looking times were interpreted to mean the babies considered the second swatch to be a new hue. Their cumulative responses showed that they distinguished among five colors: red, green, blue, purple and yellow.

The finding “suggests we’re all working from the same template,” explains lead author Alice Skelton, a doctoral student at Sussex. “You come prepackaged to make [color] distinctions, but given your culture

and language, certain distinctions may or may not be used.” For instance, infants learning Vietnamese most likely see green and blue, even if their native language does not use distinct words for the two colors.

The study systematically probed infants’ color perception, revealing how we perceive colors before we have the words to describe them, says Angela M. Brown, an experimental psychologist at the Ohio State University’s College of Optometry, who was not involved with the new research. The results add a new wrinkle to the perennial nature-versus-nurture debate and the so-called Sapir-Whorf hypothesis—the idea that the way we see the world is shaped by language.

In future work, Skelton and her colleagues are interested in testing babies from other cultures. “The way language and culture interact is a really interesting question,” she says. “We don’t yet know the exact mechanisms, but we do know how we start off.”

—Jane C. Hu

GETTY IMAGES

PHYSICS

Cutting through the Fog

A new, low-cost technique could reveal objects shrouded in mist or dust

Radar and its laser counterpart lidar can detect out-of-sight objects. But fog, rain, smoke and dust throw these tools off by scattering light and radio waves. Now Milad Akhlaghi and Aristide Dogariu, optics researchers at the University of Central Florida, have taken advantage of this property to track a moving object hidden by a simulated haze. By analyzing subtle changes an object creates in a pattern of scattered light, the researchers can instantly obtain the object’s direction and speed. The technique, reported earlier this year in *Optica*, could advance collision-

avoidance systems and help the military monitor shrouded targets.

“Tracking objects outside line-of-sight is a hot topic right now,” says Stanford University electrical engineer Gordon Wetzstein, who was not involved in the new work. Researchers have previously developed ways to image unseen objects—even around corners and behind walls—by bouncing microwave or laser pulses at them and carefully timing the signals’ return. But these methods require fancy, expensive equipment.

The Florida team came up with a simpler approach using a cheap, low-power laser and a common light detector called a photomultiplier tube, which records the total intensity of photons falling on it. To demonstrate their method, the scientists placed a moving target—a symbol printed on a transparent sheet—inside a toaster-size box of frosted plexiglass. They shined laser light on the box, whose opaque wall created a random pattern of speckles detected by a photomultiplier tube on the

other side of the box. As the object moved inside the box, the light pattern changed slightly. Using clever statistical analysis and modeling, the researchers can use these flickers to reconstruct the object’s motion in 3-D.

Like radar, the new technique can spot an object but cannot tell its size or shape, Dogariu says. It can detect objects only up to a meter away right now, but “estimates indicate that kilometer ranges might be attainable,” he adds. One limitation is that a stationary target would go unnoticed because it would not change the speckle pattern, and the method relies on tracking these changes.

Daniele Faccio of Heriot-Watt University in Scotland, who was not part of the study, calls the technique “a very elegant, robust method that requires minimal resources.” To prove its real-world efficacy, the researchers will need to show that it works when the target is in a space filled with mist and not just behind a foggy two-dimensional wall.

—Prachi Patel

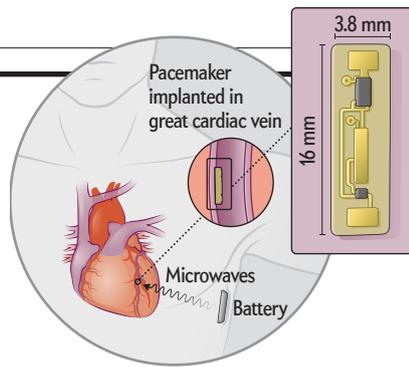
HEALTH TECH

Change of Heartbeat

Wireless pacemakers avoid some of the risks traditional devices pose

The newest, smallest pacemaker comes with no strings attached—literally. A research team at Rice University, the Texas Heart Institute and Baylor College of Medicine recently created a heartbeat regulator that gets its power via microwaves instead of wires. This greatly simplifies battery-replacement surgery and could reduce complications associated with conventional pacemakers.

Nearly 190,000 Americans received a pacemaker in 2009, the most recent year for which data were readily available. The devices have traditionally required a battery pack, embedded just below the collarbone, with leads that thread through the veins and into the heart. But “leads cause infec-



tion, and they're big, and they cause complications,” says head researcher Aydin Babakhani of Rice, who presented the product with his colleagues at a recent microwave science conference in Honolulu.

An earlier wire-free pacemaker won FDA approval in April 2016. It condensed a battery and circuit board into a pill-size implant attached to the heart's inner wall inside the right ventricle, the only chamber with enough space for the unit. When the battery dies, the entire unit must be surgically removed.

The Rice team's pacemaker combines the battery accessibility of the traditional device with the wireless feature of the 2016 version. A battery inserted below the armpit transmits power via microwaves to a capacitor implanted in the heart (*graphic*).

The capacitor triggers the muscle contractions that make the organ pump blood. The device packs a big punch for its tiny size, Babakhani says. Multiple chips, each smaller than a dime, can be inserted throughout the heart wherever needed. The pacemaker is like “a conductor of a symphony,” says Mehdi Razavi of the Texas Heart Institute and Baylor, who helped to create the device.

Babakhani says his colleagues have successfully implanted their new pacemaker in five pigs, regulating the animals' heartbeats at a variety of paces with no immediate adverse effects. The animals were euthanized after a couple of hours, Razavi says, but this fall the team begins long-term animal testing. Even if the implant works well, installing it still requires an invasive procedure, notes James Chang, an echocardiographer at Beth Israel Deaconess Medical Center and Harvard University, who was not involved in the work. But he, for one, cannot wait to see rechargeable, leadless pacemakers such as Babakhani's in the operating room: “This is certainly the way of the future.” —Leslie Nemo

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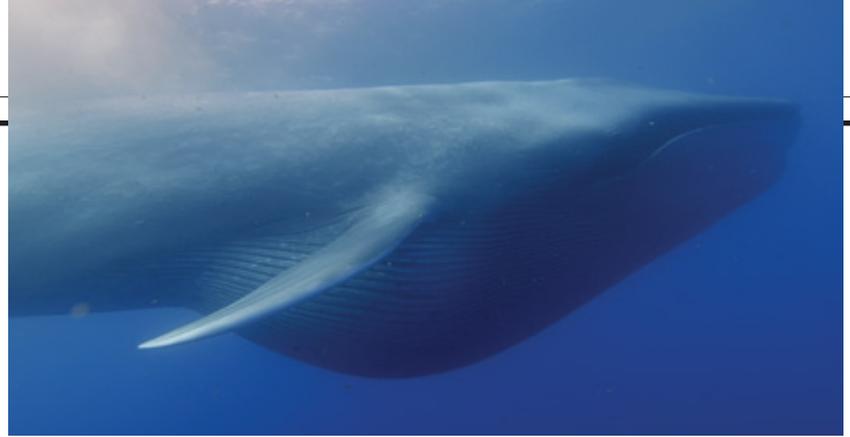
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EVOLUTION

Living Large

A new theory could explain when and why whales became so huge



The world's most massive animal, the blue whale, is like a 100-passenger jet gliding below the ocean's surface. Whales are among the largest organisms ever to exist, and now scientists say they may know when and why they evolved to be so enormous. In a study published recently in the *Proceedings of the Royal Society B*, researchers modeled the sizes of baleen whales that lived between roughly 35 million years ago and the present. The team measured the skulls (a known indicator of body size) of 63 extinct whale species from the fossil collection at the Smithsonian Institution's National Museum of Natural History. The scientists then compared these measurements against the sizes of living whales. Their analysis concluded that whale body length had varied randomly for about 30 million

years before making a leap to more than 10 meters between 4.5 million and hundreds of thousands of years ago—a stretch of time that straddles the Pliocene and Pleistocene epochs, commonly referred to as the Plio-Pleistocene—which was more recent than previous research suggested. Co-author Graham Slater of the University of Chicago notes that even studies that yielded similar time estimates were based on observation and guesswork and lacked measurements to back them up. He and his colleagues claim to be the first to use a series of statistical models to identify the timing of the change.

Pegging the trend toward giant sizes to the Plio-Pleistocene ruled out other hypothe-

ses such as the threat of predation by the huge shark megalodon—which had already been around for millions of years before the whales' growth spurt—or the advent of filter feeding, which had been around for more than 15 million years at that point.

The new work traces whales' increasing size to changes in food availability resulting from ice ages. As an ice cap formed at the North Pole, freshly cooled water would sink to the bottom of the ocean and then rise again where winds pushed warm surface waters away from the coasts in a seasonal phenomenon known as upwelling. This upward rush of cold water would have brought nutrients to the surface, allowing phytoplankton to bloom and whale prey such as krill to flourish in dense patches at certain times of the year.

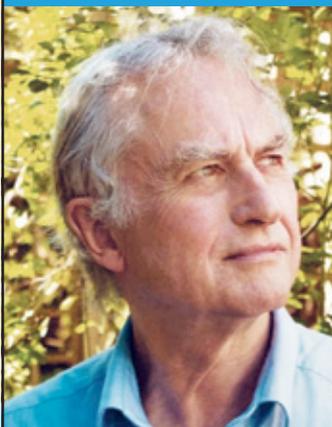
Such conditions would have offered an evolutionary boon to a bigger baleen whale, Slater explains. A larger mouth would mean taking in more water and filtering out more prey per gulp, and a larger body could more efficiently travel long distances between feedings. A slow metabolism would help conserve energy, too.

R. Ewan Fordyce, a geologist at the University of Otago in New Zealand, who has studied baleen whale fossils but was not involved in the research, agrees with the findings. But he thinks that other factors may be involved. For example, windblown, iron-rich dust may have fertilized oceanic phytoplankton and could be worth investigating further, Fordyce says.

In future studies, Slater hopes to tighten the time frame for the whales' jump in size. The literature on the Plio-Pleistocene fossil record is disappointingly sparse. "There's less incentive to work on more recent fossil records. But those are really important fossils," he notes.

—Andrea Marks

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Brock Commons, Vancouver

ENGINEERING

Wood Is the New Steel

Tall timber buildings could reduce emissions

A **wood skyscraper** might sound like a bad idea—and potentially a giant tinderbox. But architects around the world are steadily building more timber high-rises, partly with the aim of curbing carbon pollution.

Lofty wood buildings are popping up in major cities from London to Melbourne. Many more are in the works—soon Portland, Ore., will be getting its own—and they continue to break height records for modern lumber construction. The world's tallest such building completed, a 53-meter Vancouver high-rise called Brock Commons, officially opens in September.

Wood is strong, lightweight and resilient to earthquakes, says Russell Acton, a principal architect at Acton Ostry Architects, which designed Brock Commons. And the thick pieces of wood used in such buildings are in fact surprisingly fire-resistant—when burned, they form an outer layer of char that can protect the material underneath. Timber has environmental benefits as well: it is a sustainable resource—as long as forests are properly managed—and appears to emit less carbon dioxide over the course of its production (from living tree to finished building) than traditional materials such as steel and concrete. In addition, trees naturally sequester carbon and thus help to keep greenhouse gases out of the air.

Fittingly, wood is helping cities “go green.”

—Annie Sneed

BROCK COMMONS TALLWOOD HOUSE

COMPLETION DATE: 2017
 HEIGHT: 18 stories, 53 meters
 AVOIDED GREENHOUSE GAS EMISSIONS:
 679 metric tons of CO₂
 CARBON STORED IN THE WOOD:
 1,753 metric tons of CO₂
 TOTAL POTENTIAL CARBON BENEFIT:
 2,432 metric tons of CO₂

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Quick Hits

U.S.

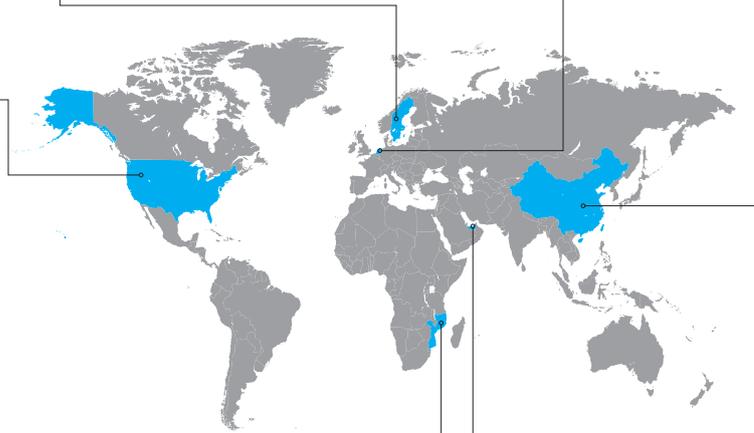
A hospital in Boise, Idaho, paid \$300,000 to move the state's largest sequoia tree two blocks down the street. Grown from a seedling sent by famed naturalist John Muir more than a century ago, the 10-story behemoth had to be moved with its surrounding soil.

SWEDEN

Starting in 2019, automaker Volvo announced plans to build only electric and hybrid vehicles, with a goal of selling one million such cars by 2025.

NETHERLANDS

In an effort to crack down on texting while biking, the Dutch Traffic Safety Association and a national telecom company created a bike lock and mobile phone app that blocks cellular service while the lock is open.



CHINA

The nation has launched its first x-ray telescope in space, which in November will begin regularly scanning the Milky Way for sources of the powerful rays.

MOZAMBIQUE

Years of civil war have taken a toll on wildlife populations. Zinave National Park has now begun the lengthy process of restocking its habitats with more than 7,500 animals from other parks and neighboring countries.

UNITED ARAB EMIRATES

Earlier this summer Dubai debuted its first robot cop, a device with a touch screen on its chest for reporting crimes. Law-enforcement officials hope to have robots make up a quarter of the force by 2030.

For more details, visit www.ScientificAmerican.com/sep2017/advances

—Leslie Nemo

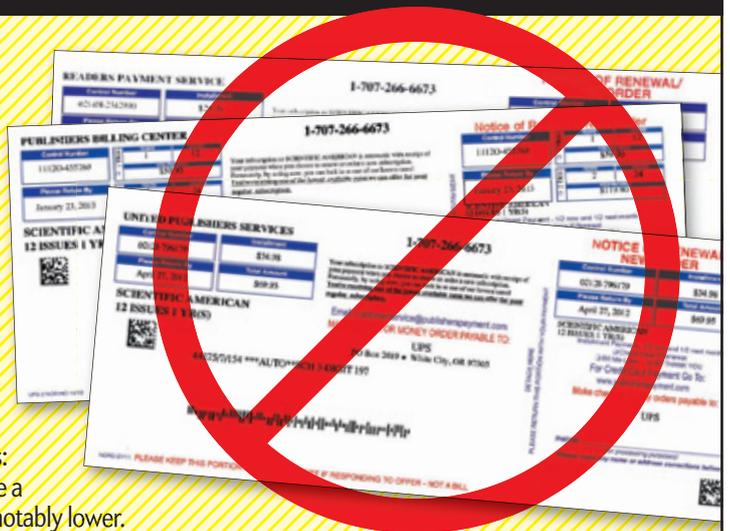
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SLEEP SCIENCE

Night Owl Genes

A mutation that affects the circadian clock may be keeping people up late

Some people, no matter what they do, simply cannot fall asleep until the wee hours—and do not feel rested unless they get up much later than most of us. These night owls may have a common form of insomnia called delayed sleep phase disorder (DSPD), which studies have suggested is at least partly heritable. Now researchers at the Rockefeller University and their colleagues have uncovered a genetic mutation that could elucidate what causes these often awkward sleep schedules.

Of course, DSPD is not a problem for everyone who has it: if you work as a bartender or a musician, you might never seek a diagnosis or treatment, says lead study



author Alina Patke, a sleep researcher at Rockefeller, who self-identifies as a night owl but does not have the mutation. Yet for others, especially college students or office workers, the condition can be torture. The new study centered on a 46-year-old female subject with lifelong sleep problems. “Typically she would go to bed at 2 or 3 A.M., sometimes as late as 5 or 6,” Patke says.

The woman lived under observation for 14 days in a room with no clocks or windows. Not only did she produce the sleep-inducing hormone melatonin five to seven hours later than a typical person in similar previous studies, but her sleep was also oddly fragmented, sometimes coming in short naps. When the team analyzed her

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DNA, they found a mutation in a gene called *Cry1* that also showed up in her family members who reported sleep problems. This gene encodes a protein that is known to suppress the action of the core circadian clock proteins CLOCK and BMAL, which activate a wide variety of genes—including some related to wakefulness—during the day. The mutation caused the deletion of a portion of the CRY1 protein’s tail, making it even more effective at suppressing CLOCK and BMAL. The team sifted through a genetic database and found 39 other people with the mutation. Most of them also had relatively late bedtimes and wake-up hours.

Daniel Kripke, a psychiatrist who has studied sleep and a professor emeritus at the University of California, San Diego, who was not involved in the work, points out that studies that scan large groups of people for links between a particular trait and a genetic variant have found no connection between this mutation and DSPD. Still, he says, the new paper presents convincing evidence that it could be behind some cases of the disorder. —Veronique Greenwood



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Tactile traffic maps could help blind pedestrians navigate intersections by indicating the number of lanes and direction of traffic.



TECHNOLOGY

Navigating by Touch

Tactile maps could help blind pedestrians cross increasingly complex intersections

People in many cities risk their lives every time they cross the street. In New York City, pedestrian deaths accounted for the majority of yearly traffic fatalities continually since 2006, according to government data. For visually impaired people, the situation is uniquely dangerous and getting worse.

Over the past summer designers at Touch Graphics, a company that makes navigation technology that incorporates information from several senses, have been working with New York's Department of Transportation to test tactile maps—diagrams with three-dimensional features and braille text—at a busy intersection near a resource center for blind people. The project is part of the city's ini-

tiative to eliminate pedestrian traffic fatalities. If the trial is successful, these maps could be installed at all New York's 13,000 traffic lights, according to Touch Graphics president Steven Landau.

Landau says such maps are important because increasingly complex street layouts are making it harder for visually impaired pedestrians to know what they will find after stepping off the curb. The technology has been tried in Denmark and Sweden, but the New York trial is a first for North America, according to Landau. San Francisco and Toronto may soon test such systems as well, he adds.

Landau's team created the maps using ultraviolet printing: ink is printed on a surface, then passed under a UV light that cures it before it can air-dry. This process allows for more detail and less ink spreading, which is especially useful for creating raised graphics that are crisp and clear enough to be felt by touch. Each map uses 3-D shapes and bright, high-contrast colors to depict the intersection from one of the eight possible perspectives of some-

one about to cross it. A raised circle labeled "You are here" in both braille and standard text shows a pedestrian's starting point, and a dotted line traces the path to be walked. Oval shapes symbolize vehicles, with raised arrows at one end of each "car" to show the direction of traffic in a given lane. A row of black bars represents a bike lane, and medians and islands are customized to show their actual shapes.

Sile O'Modhrain, who studies haptic technology at the University of Michigan and is not involved in the project, thinks these maps could change lives. O'Modhrain, who is blind, says complex intersections in Ann Arbor, Mich., limit the places she can live. "I think this would be a fantastic idea because when you arrive at a street crossing, it's always difficult to know how many lanes of traffic you're going to have to accommodate," she says. Even though she can hear the volume of traffic and can sense which way it is coming from, O'Modhrain adds, labeling turning lanes could be a useful feature.

—Andrea Marks

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HOW WELL GETS DONE

Pediatric Predicament

New initiatives aim to lessen the obstacles to finding useful treatments for children

By Charles Schmidt

Parents considering whether to enroll a sick son or daughter in a clinical trial often face a barrage of conflicting emotions. On one hand, they hope that the experiment will lead to a breakthrough in treatment. On the other, they must deal with the uncertainty and fear that come from willingly exposing their child to an unproven therapy that could turn out to be ineffective or even more harmful than standard treatment. What parents may not anticipate, however, is that their child's contribution to scientific understanding could also be squandered on a study that is never completed or that fails to be published in the medical literature.

Such wasted effort is a strong possibility, according to a 2016 study. Harvard University researchers reviewed the more than 550 pediatric clinical trials that were registered with the U.S. federal government over a three-year period between 2008 and 2011 and found that more than 40 percent were never finished or that they were completed but never published even five years later. In total, more than 77,500 children participated in studies that contributed little or nothing to advance treatments for their illnesses because the research disappeared from scientific view. Apart from the loss of time, money and resources, these failures are also "tragic because we have so little clinical trial information on children to begin with," says Florence Bourgeois, an assistant professor of pediatrics and emergency medicine at Harvard Medical School, who co-authored the study.

Efforts to improve the situation are under way. Researchers at universities and medical centers are studying their own workflows to uncover hidden roadblocks to enrollment in pediatric clinical trials. At the same time, the National Institutes of Health is bringing together experts from academia, industry and government to try to make trial results more widely available. Although progress has been gradual, proponents believe they are on the right track.

HITTING A WALL

FOR DECADES physicians who wanted to prescribe a particular medication for a youngster adjusted the dosage downward from the amounts given to adults based merely on the child's weight. But youngsters are not just pint-sized adults. Their physiology changes rapidly as they move from infancy through adolescence, which means that various drugs may trigger unpredictable effects in their body. Infants do not metabolize an anesthetic

called propofol, for example, at the same rate as adults, which leads to toxic buildups in babies. Newborns, children and adults also break down antiseizure drugs differently, making it difficult to estimate safe doses on the basis of weight and size alone.

Whereas clinical studies of adults have taken place in the U.S. for well over 100 years, pharmaceutical companies did not regularly test their products in children until the 1990s, when the federal government began offering financial incentives to do so. The Food and Drug Administration Modernization Act of 1997 provided companies six months of additional patent protection for every drug they tested in children, and after that, a nascent pediatric clinical trial infrastructure began taking shape. Additional laws expanded on those offerings and created programs for pediatric drug development at the NIH.

Nevertheless, the problem of mismatched physiologies remains, and many physicians are understandably nervous about calculating the right dosages. But their reluctance is not the only challenge. After excluding trials that were still recruiting participants or had not yet begun enrolling them, the Harvard team found that the biggest reason why studies failed was that they could not attract enough children to participate in the first place.

Lack of enrollment is often a problem with adult trials as well, but pediatric investigations face unique challenges. Pediatricians in community practice may not have enough time to participate in clinical research, especially if they work far from academic hospitals where supportive resources for clinical trials are readily available. Moreover, there simply are not as many children as adults. Just 20 percent of the U.S. population is younger than 14 years of age. Furthermore, children are, thankfully, much less likely than adults to suffer serious illnesses. "So by definition, most childhood diseases are rare," says Danny Benjamin, a professor of pediatrics at the Duke University School of Medicine.

Ronnie Guillet knows all about enrollment challenges from firsthand experience. A professor of neonatology at the University of Rochester, Guillet had to shut down a clinical trial in 2014 that would have clarified how long newborn infants should be treated if they develop seizures. About one in 200 babies suffers seizures within days of birth, and doctors disagree on how long to give those infants antiseizure medications. Some continue treatment only until the seizures stop. Others prolong the drugs for several weeks or even months in an attempt to keep the seizures from recurring.

Guillet worried that extended treatment might harm an infant's brain, although she also knew that repeated seizures can cause neurological damage. The only way to know how to balance potential benefits and risks was to conduct a clinical trial. Thus, after randomly assigning infants to one approach or the other, she planned to monitor their neurological development. She needed to enroll 250 babies within two years to have a large enough sample size to feel confident that her results were statistically reliable.

But parents—and, somewhat surprisingly to Guillet, neonatal nurses—were skeptical. "Some worried about putting kids on



Charles Schmidt is a science journalist based in Portland, Me.

the extended therapy, and others worried about the placebo,” Guillet says. “They had similar fears but for opposite reasons.” She had to cancel the study when only 13 children had enrolled after a year, and her underlying question remains unanswered.

Attracting the required number of participants for a study does not, however, guarantee it will be published or that the results can be widely shared. Drug companies, for example, have a good track record for enrolling enough children to finish their investigations. But fewer of their results actually appear in a scientific journal by comparison with academic trials paid for by the NIH or other independent organizations. “Drug companies care about publication only if the results support their commercial goals,” Harvard’s Bourgeois says. In other words, they tend to publish only the studies with positive results. As she and her colleague wrote in their 2016 paper, they consider nonpublication a “violation of the ethical imperative to share results of trials that involve human subjects.” Researchers at universities, on the other hand, live or die by their publication record, Bourgeois explains, so “you’d expect that the academic trials would generate more published studies, and that’s what we saw.”

A MATTER OF TRUST

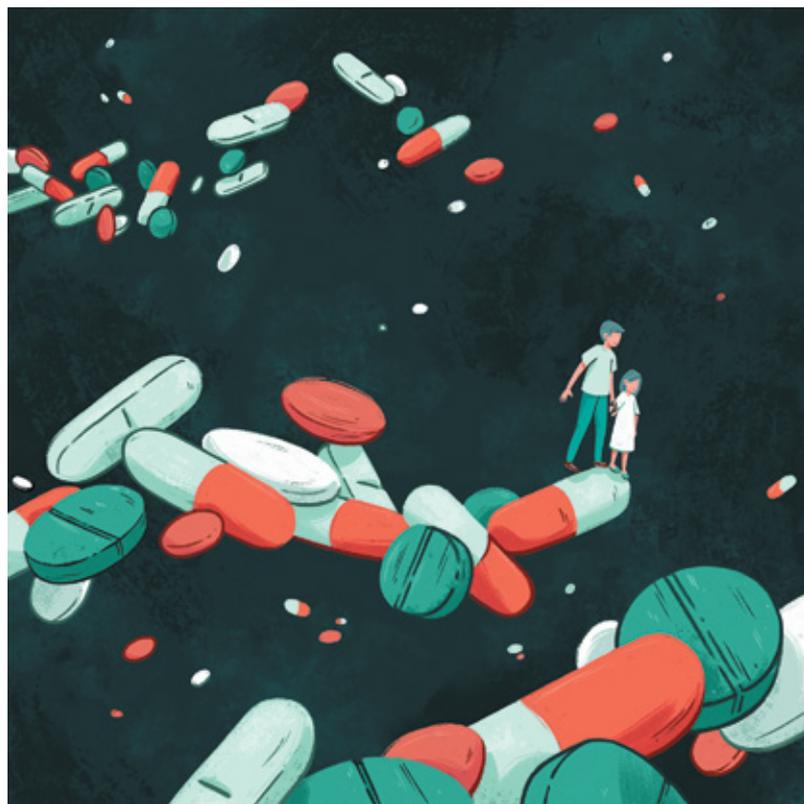
MAKING IMPROVEMENTS in a complex process such as a clinical trial generally requires greater coordination and collaboration among several groups of people. Last fall the NIH launched a new Trial Innovation Network that brings together industry, regula-

tory agencies, universities and other organizations to increase the number of underserved populations—including children—who are helped by medical studies. Among the challenges the network has identified is the need for better communication among the professionals who try to enroll new participants in a trial—known as recruiters—and the children’s caregivers.

“Recruiters generally don’t take enough time to understand the day-to-day circumstances and motivations of the populations they’re trying to enroll,” says Yvonne Joosten, who directs one of the network’s newly funded programs, based at the Vanderbilt University Medical Center. Together with colleague Tiffany Israel, Joosten has begun coordinating community meetings on behalf of clinical trial investigators before their studies are launched. During these “listening sessions,” as she calls them, Joosten talks with families to learn more about the barriers that might keep them from participating. Transportation to and from study sites could be a deterrent, or parents might feel there is no value in getting involved should their children be assigned to a control group. “Researchers aren’t obligated to take advice from community members, but those that do are often happy with the results,” she says.

On the publication front, federal agencies are flexing some regulatory muscle to ensure that investigators make their results available for others to see—whether or not they appear in a scientific journal. Investigators in the U.S. are required to register new trials and post final results on a searchable NIH database found at ClinicalTrials.gov. And those that do not can face stiff penalties under a law known as the Food and Drug Administration Amendments Act of 2007. The FDA can fine noncompliant drug companies \$10,000 a day, and the NIH can pull support from its sponsored scientists. But in practice, not one company or NIH-funded scientist has ever been penalized. According to Jerry Sheehan, assistant director for policy development at the National Library of Medicine, the 2007 law is full of ambiguities about which clinical trials had to register with the site and what kinds of results they had to report.

In an attempt to eliminate any loopholes, the Department of Health and Human Services (of which both the NIH and FDA are a part) issued a lengthy ruling that clarifies what is required in exhaustive detail. That rule became enforceable in January. Whether it provides clinicians with enough information to prescribe new medications—or to prevent unnecessary or even dangerous treatments—for children remains to be seen. But this and other efforts should, at the very least, reduce the chances that the contributions made by the youngest participants of scientific studies will be lost. ■



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SPEAKERS:



David Stevenson, Ph.D.

Dr. David Stevenson is the Marvin L. Goldberger Professor of Planetary Science at the California Institute of Technology and an expert on the

origin, evolution, and structure of planets. He is a New Zealander who came to the United States as a graduate student, obtaining a Ph.D. in theoretical physics at Cornell University in 1976, where he worked on the interior of Jupiter. Most of his subsequent career has been in the USA and he has been on the faculty at Caltech since 1980, serving as a Division Chair and Chair of the Faculty along the way. His awards and honors include membership in the National Academy of Science, Fellow of the Royal Society (London), the Urey Prize (awarded by the American Astronomical Society) and the Hess Medal (awarded by the American

Geophysical Union). On occasion, he has participated in advising movie and TV directors on the science in their productions.



Chris Stringer, Ph.D.

Dr. Chris Stringer has worked at The Natural History Museum London since 1973, and is now Research Leader in Human Origins and a Fellow of the Royal

Society. His early research was on the relationship of Neanderthals and early modern humans in Europe and he now collaborates with archaeologists, dating specialists, and geneticists in attempting to reconstruct the evolution of modern humans globally. He has excavated at sites worldwide, and is currently co-directing the Pathways to Ancient Britain project, funded by the Calvea Foundation. He has published over 200 scientific papers, and his recent books include *The Complete*

World of Human Evolution (revised edition 2011, with Peter Andrews), the award-winning *Homo Britannicus* (2006), *The Origin of Our Species* (UK 2011), alternative title (US, March 2012): *Lone Survivors: How We Came to Be the Only Humans on Earth*, and *Britain: One Million Years of the Human Story* (2014, with Rob Dinnis).



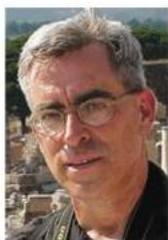
Max Tegmark, Ph.D.

A native of Stockholm, Dr. Max Tegmark received his B.Sc. in Physics from the Royal Institute of Technology and a B.A. in Economics

at the Stockholm School of Economics. He studied physics at the University of California, Berkeley, earning his Ph.D. in 1994. Dr. Tegmark was a research associate with the Max-Planck-Institut für Physik in Munich, a Hubble Fellow and member of the Institute for Advanced Study, Princeton,



and an Assistant Professor at the University of Pennsylvania before arriving at MIT in September 2004. Dr. Tegmark is an author on more than 200 technical papers, and has featured in dozens of science documentaries. His awards include a Packard Fellowship (2001–06), Cottrell Scholar Award (2002–07), and an NSF Career grant (2002–07), and he is a Fellow of the American Physical Society. His work with the SDSS collaboration on galaxy clustering shared the first prize in Science magazine's "Breakthrough of the Year: 2003."



Stephen Ressler, Ph.D.

Dr. Stephen Ressler is Professor Emeritus from the United States Military Academy at West Point and a Distinguished Member of the American Society of Civil Engineers (ASCE). He served for 34 years as a commissioned

officer in the U.S. Army Corps of Engineers and retired at the rank of Brigadier General in 2013. In 2007, he deployed to Afghanistan to create a civil engineering program for the newly created National Military Academy of Afghanistan in Kabul. Dr. Ressler is passionate about communicating the joys of engineering to inquiring minds of all ages. His three video lecture series — *Understanding the World's Greatest Structures*, *Understanding Greek and Roman Technology*, and *Everyday Engineering* — are among the most highly-rated offerings in The Great Courses' catalog. Dr. Ressler has received numerous awards and his Bridge Designer software has been used by over two million students worldwide. He is also a developer and principal instructor for the ASCE Excellence in Civil Engineering Education Teaching Workshop.

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David Pogue is the anchor columnist for Yahoo Tech and host of several NOVA miniseries on PBS.

Cut That Last Cord

Charging your phone wirelessly all day long may not be far off

By David Pogue

Sooner or later everything goes wireless. Over the decades we've figured out how to eliminate the cables that bring us sound, video, text, phone calls and data. Today there's only one major cable left to eliminate: the power cord.

Imagine if we could tap into power wirelessly! We'd all quit bellyaching about our phones being dead by dinnertime. Battery life would become a meaningless spec. A new era of gadgets could be thinner, sleeker, lighter and more flexible—because they wouldn't have to devote such a huge chunk of their volume to batteries.

And by “wireless charging,” I don't mean the lame idea of setting down your phone on a charging pad every night, as you can with some smartphones. That saves you plugging in a cord, but you can't use your phone while it's charging. No, we want to be able to keep our gadgets in our pockets, charging during the day. Charging through the air has been the holy grail for a handful of start-ups for nearly a decade—and an obsession of my own for two years. Several outfits, flush with venture-capital cash, are working hard on it, presenting demos and getting observers ex-

cited. Wireless charging would be popular, profitable and transformative. So what's the holdup?

To start with, most of these technologies work by transmitting RF (radio-frequency) waves. Our future phones, tablets, laptops, watches and Fitbits will have to be equipped with compatible receivers that convert these Wi-Fi-like waves back into power.

That, for example, is how Powercast's technology works. Since 2010 this company has been selling industrial products, such as equipment sensors and active RFID tags, that can recharge at a distance. It hopes to get into consumer products soon.

Unfortunately, Powercast's technology transmits only microwatts or milliwatts (millionths or thousandths of a watt), which is nowhere close to enough for charging a phone. Even worse, it can't track your gadget's position in the room; you have to leave the device in a predefined spot. Charles Greene, chief operating officer, says that he imagines that you'll set your phone down on the bedside table every night.

Well, cool. But not what the world is hoping for.

Companies such as Ossia and Energous have a more ambitious plan. Their transmitters contain an array of hundreds of antennas, which pinpoint your device as you move around. Now that's more like it, right?

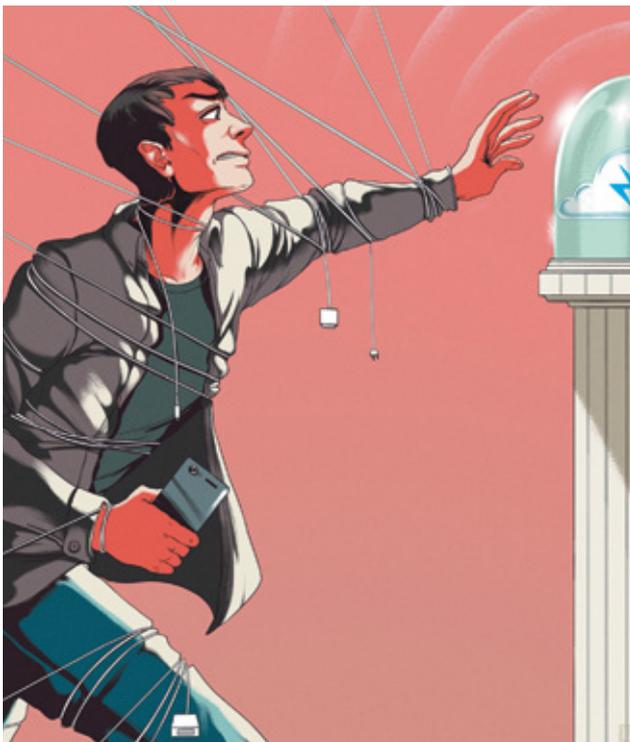
Well, yes. Yet here again, the dream of phones charging in our pockets is elusive. Energous marketing officer Gordon Bell says his products will trickle-charge your phone through the air—when it's in your pocket. But if you're *using* the phone during the day, the best you can hope for is that the transmitter will keep the battery level from going down.

Then there's uBeam, which uses ultrasonic waves to transmit power. Unfortunately, this technology requires line of sight to the transmitter—so you have to hold your body in the same position all day. (Furthermore, uBeam's former vice president of engineering now says the technology will never work.)

And there's the Federal Communications Commission problem. You can't sell wireless tech in the U.S. until the FCC has concluded that it's safe and doesn't interfere with existing wireless products. At the moment, the agency permits wireless transmission in two categories: very low power at a distance (such as Wi-Fi) or higher power that is contained or localized (such as microwaves or charging pads). Clearly, neither category currently permits long-range, higher-power transmission.

Energous asserts that its power transmission is, in effect, localized, thanks to that beam-forming array. If the FCC buys that argument, then it and its rivals might have a shot at bringing their products to market.

The company says that it expects to have FCC approval of its first through-the-air charger, a desktop model with a three-foot range, by the end of this year. If that comes to pass and if the world's makers of consumer products take the bait, then we may be in luck. Maybe 2018 will be the year the last wire went away. **SA**



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PROMOTION

The Agenda Setters

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Disruptive Innovations in Biomanufacturing

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As part of our partnership with EDB Singapore, Scientific American's Custom Media Division recently convened senior executives from the biotech industry to discuss trends in biopharmaceutical manufacturing at a salon dinner event in Cambridge.

The wide-ranging discussion was moderated by **Andrew Marshall**, Chief Editor, Nature Biotechnology and co-moderated by **Keith Carson**, Editor in Chief, Bioprocessing Journal. **Jeremy Abbate**, VP & Publisher Scientific American and **Mr. Yi-Hsen Gian**, Regional President, Americas, EDB Singapore gave opening remarks and welcomed the group.

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THIS IS NOT A WOMEN

Why the New Science of Sex &

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**PROMISCUOUS MEN,
CHASTE WOMEN
AND OTHER
GENDER MYTHS**
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6.
LIFE BEFORE ROE
BY RACHEL BENSON GOLD
AND MEGAN K. DONOVAN
page 58

SEX IS SUPPOSED TO BE SIMPLE—at least at the molecular level. The biological explanations that appear in textbooks amount to $X + X = ♀$ and $X + Y = ♂$. Venus or Mars, pink or blue. As science looks more closely, however, it becomes increasingly clear that a pair of chromosomes do not always suffice to distinguish girl/boy—either from the standpoint of sex (biological traits) or of gender (social identity).

In the cultural realm, this shift in perspective has already received a wide embrace. “Nonbinary” definitions of gender—transfeminine, genderqueer, hijra—have entered the vernacular. Less visible perhaps are the changes taking place in the biological sciences. The emerging picture that denotes “girlness” or “boyness” reveals the involvement of complex gene networks—and the entire process appears to extend far beyond a specific moment six weeks after gestation when the gonads begin to form.

To varying extents, many of us are biological hybrids on a male-female continuum. Researchers have found XY cells in a 94-year-old woman, and surgeons discovered a womb in a 70-year-old man, a father of four. New evidence suggests that the brain consists of a “mosaic” of cell types, some more yin, others further along the yang scale.

These findings have far-reaching implications beyond just updating the biology textbooks. They have particular bearing on issues of personal identity, health and the economic well-being of women. That is because arguments about innate biological differences between the sexes have persisted long past the time they should have been put to rest.

In 1895 an article in *Scientific American*—“Woman and the Wheel”—raised the question of whether women should be allowed to ride bicycles for their physical health. After all, the article concluded, the muscular exertion required is quite different from that needed to operate a sewing machine. Just Championnière, an emi-

'S ISSUE

Gender Matters for Everyone

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ment French surgeon who authored the article, answered in the affirmative the question he had posed but hastened to add: “Even when she is perfectly at home on the wheel, she should remember her sex is not intended by nature for violent muscular exertion.... And even when a woman has cautiously prepared herself and has trained for the work, her speed should never be that of an adult man in full muscular vigor.”

Of course, 19th-century attitudes might be dismissed out of hand for their droll quaintness. Yet as *Scientific American's* current annual in-depth look at a topic of pressing interest shows, embedded notions of women's inferiority persist well into the 21st century. This penchant holds true even in the sciences, where some fields emphasize intellectual brilliance—erroneously associated with white males—as a prerequisite for success, an attitude that drives away female prospects in physics and mathematics.

Since Championnière wrote for *Scientific American*, women's status has undeniably improved. Globally, in countries rich and poor, women have made strides in education and reproductive health and taken on more decision-making roles. It's not enough, though. Economic barriers persist that prevent women from gaining access to capital and jobs and getting paid a decent wage for the jobs they do find. More energy must be devoted as well to researching how diseases affect the sexes differently—and to adapting medical treatments to women's needs. For an interlinked world to thrive, women must be further empowered to hold up their half of the sky—an issue that should demand as much attention as climate change and nuclear arms control.

Change will only continue if the institutions that matter stay open to it. The assault on women's health by Republican lawmakers in Washington looms as a formidable obstacle. Women's well-being needs to be seen as an issue for everyone, regardless of political affiliation. The new science of sex and gender holds the prospect of helping shape public perception and policy making to acknowledge this reality.

—The Editors



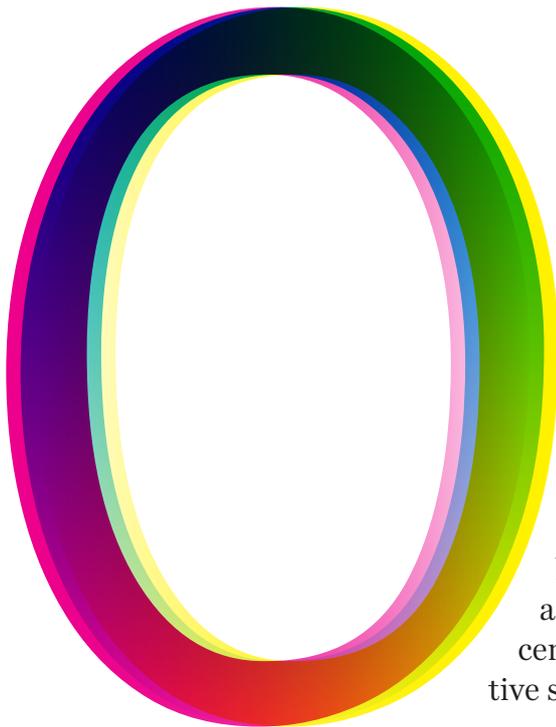
PROMISCUOUS MEN, CHASTE WOMEN AND OTHER GENDER MYTHS

The notion that behavioral differences between the sexes are innate and immutable does not hold up under scrutiny

BY CORDELIA FINE AND MARK A. ELGAR

Illustrations by Yuko Shimizu





ONE OF AUSTRALIA'S MORE PROVOCATIVE ART MUSEUMS, the Museum of Old and New Art in Hobart, Tasmania, recently hosted an exhibition on the evolution of art. Three evolutionary scientists who guest-curated the show offered their perspectives on how evolution explains not just the characteristics of amoebas, ants and antelopes but also the uniquely human endeavor of art. One of these explanations sees art as an evolved trait akin to the peacock's effervescently colored tail, which increases its bearer's reproductive success by signaling superiority as a mate.

Hands up if this scenario conjures in your mind the image of a much feted female artist, famous for fearlessly pushing the boundaries of artistic convention, pleasurably making her way through a series of handsome young male muses? We didn't think so.

The stereotype of the daring, promiscuous male—and his counterpart, the cautious, chaste female—is deeply entrenched. Received wisdom holds that behavioral differences between men and women are hardwired, honed by natural selection over millennia to maximize their differing reproductive potentials. In this view, men, by virtue of their innate tendencies toward risk-taking and competitiveness, are destined to dominate at the highest level of every realm of human endeavor, whether it is art, politics or science.

But a closer look at the biology and behavior of humans and other creatures shows that many of the starting assumptions that have gone into this account of sex differences are wrong. For example, in many species, females benefit from being competitive or playing the field. And women and men often have similar preferences where their sex lives are concerned. It is also becoming increasingly clear that inherited environmental factors play a role in the development of adaptive behaviors; in humans, these factors include our gendered culture. All of which means that equality between the sexes might be more attainable than previously supposed.

FAST MALES, FINICKY FEMALES

THE ORIGIN of the evolutionary explanation of past and present gender inequality is Charles Darwin's theory of sexual selection. His observations as a naturalist led him to conclude that, with some exceptions, in

the arena of courtship and mating, the challenge to be chosen usually falls most strongly on males. Hence, males, rather than females, have evolved characteristics such as a large size or big antlers to help beat off the competition for territory, social status and mates. Likewise, it is usually the male of the species that has evolved purely aesthetic traits that appeal to females, such as stunning plumage, an elaborate courtship song or an exquisite odor.

It was, however, British biologist Angus Bateman who, in the middle of the 20th century, developed a compelling explanation of *why* being male tends to lead to sexual competition. The goal of Bateman's research was to test an important assumption from Darwin's theory. Like natural selection, sexual selection results in some individuals being more successful than others. Therefore, if sexual selection acts more strongly on males than females, then males should have a greater range of reproductive success, from dismal failures to big winners. Females, in contrast, should be much more similar in their reproductive success. This is why being the animal equivalent of a brilliant artist, as opposed to a mediocre one, is far more beneficial for males than for females.

Bateman used fruit flies to test this idea. Although the technology for paternity testing did not exist at the time, he inferred parentage and the number of different mates of males and females as best he could. He did this rather ingeniously, by using fruit flies with different genetic mutations, including one that makes the bristles on the wings extra long, another that makes the wings curl upward, and yet another that renders the eyes very small or absent. These mutations are sometimes evident in offspring, so Bateman could estimate how many offspring each adult produced by

IN BRIEF

The classic evolutionary explanation

of behavioral differences between men and women holds that they reflect an evolved pattern seen across the animal kingdom. Many gender gaps, in this view, are thus "natural."

But research has shown

that many of the foundational assumptions of this account are wrong.

Environmental factors,

moreover, can play a key role in the development of evolved behaviors. Progressive cultural shifts do not "go against" nature but rewrite it.

counting the number of different mutants among the surviving offspring. From his data, he concluded that males were indeed more variable than females in their reproductive success (measured as offspring). Bateman also reported that only male reproductive success increased with the number of mates. This result, he argued, is why males compete and females choose: a male's reproductive success is largely limited by the number of females he can inseminate, whereas a female reaches her plateau with a single mate that provides her with all the sperm she needs.

Scholars mostly ignored Bateman's study at first. But some two decades later evolutionary biologist Robert Trivers, now at Rutgers University, catapulted it into scientific fame. He expressed Bateman's idea in terms of greater female investment in reproduction—the big, fat egg versus the small, skinny sperm—and pointed out that this initial asymmetry can go well beyond the gametes to encompass gestation, feeding (including via lactation, in the case of mammals) and protecting. Thus, just as a consumer takes far more care in the selection of a car than of a disposable, cheap trinket, Trivers suggests that the higher-investing sex—usually the female—will hold out for the best possible partner with whom to mate. And here is the kicker: the lower-investing sex—typically the male—will behave in ways that, ideally, distribute cheap, abundant seed as widely as possible.

The logic is so elegant and compelling it is hardly surprising that contemporary research has identified many species to which the so-called Bateman-Trivers principles seem to apply, including species in which, unusually, it is *males* that are the higher-investing sex. For example, in some species of katydids, also known as bush crickets, the male's investment in reproduction is greater than the female's, thanks to a nutrient-rich package he provides, along with sperm, during copulation. Females thus fight one another for access to males.

The Bateman-Trivers principles also seem to provide a plausible explanation of the gender dynamics of human societies. Women are commonly understood to have less interest in casual sex with multiple partners, for instance, and to be more caring and less competitive and risk-taking. Applying the Bateman-Trivers logic, these behaviors serve to protect their investment. Contemporary advice from Facebook's chief operating officer Sheryl Sandberg to women to "lean in" at work to rise to the top thus appears to be undercut by arguments that predispositions to take risks and compete have evolved more strongly in males than in females because of greater reproductive return.

BREAKING THE RULES

BUT IT TURNS OUT that nature is not nearly so simple and neat as this line of reasoning would suggest, even for nonhuman animals. In the decades since the Bateman-Trivers principles were forged, many of their foundational assumptions have been overturned. One such change in thinking concerns the supposed cheapness

of reproduction for males. Sperm is not always cheap, nor is it always abundant: for instance, male stick insects can take several weeks to recover their libido after a lengthy copulation. And more recent scrutiny of the fruit fly's reproductive habits found that males do not always take up mating opportunities. Male selectivity has consequences for females of many insects, because if they mate with a male that has copulated extensively, they risk acquiring insufficient sperm. Scarce or limited sperm is not an uncommon challenge for females, which may mate repeatedly with different males precisely to acquire enough sperm.

In fact, a reexamination of Bateman's data from the lab of Patricia Gowaty of the University of California, Los Angeles, revealed, crucially, that a female fruit fly's reproductive success also increased with her mating frequency, a pattern that has emerged for a great many other species of animals. Furthermore, field studies show that mating for females is not the given scientists once assumed it to be. In a surprisingly large number of species, a significant proportion of females do not encounter a male and are thus unable to reproduce. Nor is promiscuous mating standard practice for males. Monogyny, in which males mate only once, is not uncommon and can be an effective means of maximizing reproductive success.

Insects are not the only creatures that challenge the Bateman-Trivers principles. Even in mammals, for which investment in reproduction is particularly skewed because of the costs of gestation and lactation for females, competition is important not just for male reproductive success but also for female reproductive success. For example, the infants of higher-ranking female chimpanzees have higher rates of both arrival and survival than those of lower-ranking females.

In our own species, the traditional story is additionally complicated by the inefficiency of human sexual activity. Unlike many other species, in which coitus is hormonally coordinated to a greater or lesser degree to ensure that sex results in conception, humans engage in a vast amount of nonreproductive sex. This pattern has important implications. First, it means that any one act of coitus has a low probability of giving rise to a baby, a fact that should temper overoptimistic assumptions about the likely reproductive return on seed spreading. Second, it suggests that sex serves purposes beyond reproduction—strengthening relationships, for example.

Cultural and societal changes further necessitate rethinking the application of Bateman-Trivers principles to humans. The dichotomous view of the sexes that held sway in the last century has given way to one that sees differences mainly in degree rather than kind. Increased female sexual autonomy wrought by the birth-control pill and the sexual revolution has led to marked increases in premarital sex and numbers of sexual partners in women especially. And women and men report largely similar preferences for their sex lives. For example, the second British National Survey



Cordelia Fine is a professor of history and philosophy of science at the University of Melbourne and a Women's Leadership Institute Australia Fellow. Her most recent book is *Testosterone Rex: Myths of Sex, Science, and Society* (W. W. Norton, 2017).



Mark A. Elgar is a professor of evolutionary biology at the University of Melbourne. His research group focuses on questions about the evolutionary significance of cooperative and mating behaviors and studies the role of chemical and visual communication in facilitating those behaviors.



of Sexual Attitudes and Lifestyles, based on a random sample of more than 12,000 people between the ages of 16 and 44 surveyed around the turn of this century, found that 80 percent of men and 89 percent of women preferred monogamy.

Meanwhile the feminist movement increased women's opportunities to enter, and excel in, traditionally masculine domains. In 1920 there were just 84 women studying at the top 12 law schools that admitted women, and those female lawyers found it nearly impossible to find employment. In the 21st century women and men are graduating from law school in roughly equal numbers, and women made up about 18 percent of equity partners in 2015.

RISKS AND BENEFITS

AS WE ZOOM IN from this broad-brush perspective on gender patterns to a fine-grained examination of sex differences in behavior, the familiar evolutionary story becomes even muddier. Consider risk-taking, once assumed to be a masculine personality trait, thanks to its role in enhancing male reproductive success. It turns out that people are quite idiosyncratic in the kinds of risks they are willing to take. The skydiver is no more likely to gamble money than the person who prefers to exercise in the safety of the gym. It is people's perception of the potential costs and benefits of a particular risky action, not their attitude toward risk per se, that explains their willingness to take risks. These perceived costs and benefits can include not only material losses and gains but also less tangible impacts on reputation or self-concept.

This nuance is important because sometimes the balance of risks and benefits is not the same for men and women because of physical differences between the sexes or gendered norms, or both. Consider, for example, the risk of a casual sexual encounter. For a man, the gains include the near certainty of an orgasm and perhaps a burnishing of his reputation as a "stud." For a woman, sexual pleasure is far less likely from casual sex, according to a large-scale study of North American students published in 2012 by Elizabeth Armstrong of the University of Michigan and her colleagues. And thanks to the sexual double standard, her reputation is more likely to be damaged by the episode. Among young Australians, for example, sociologist Michael Flood, now at the Queensland University of Technology, found that the label "slut" retains a stronger "moral and disciplinary weight ... when applied to women." Moreover, a woman bears greater physical risks, including pregnancy, sexually transmitted disease and even sexual assault.

The lens of different risks and benefits can also clarify the sexes' different propensity to assert themselves at work, as Sandberg has advised women to do. It is hard to see how a young female lawyer, looking first at the many young women at her level and then at the very few female partners and judges, can be as optimistic about the likely payoff of leaning in and making sacrifices for her career as a young male lawyer. And this is before one considers the big-picture evidence of sexism, sexual harassment and sex discrimination in traditionally masculine professions such as law and medicine.

Still, the idea that a nonsexist society could erase the psychological effects of timeless, enduring sex differences in reproductive investment seems implausible to many. A recent article in the *Economist*, for example, equated the marketing-inspired tradition of the diamond engagement ring with the strutting peacock's extravagant tail, an evolved courtship ritual that signals a man's resources and commitment. The journalist wrote that "greater equality for women might seem to render male-courtship displays redundant. But mating preferences evolved over millennia and will not change quickly."

ENVIRONMENTAL INFLUENCE

ALTHOUGH SEX certainly influences the brain, this argument overlooks the growing recognition in evolutionary biology that offspring do not just inherit genes. They also inherit a particular social and ecological environment that can play a critical role in the expression of adaptive traits. For example, adult male moths that hailed, as larvae, from a dense population develop particularly large testes. These enhanced organs stand the moths in good stead for engaging in intense copulatory competition against the many other males in the population. One would be forgiven for assuming that these generously sized gonads are a genetically determined adaptive trait. Yet adult male moths of the same species raised as larvae in a lower-density population instead develop larger wings and antennae, which are ideal for searching for widely dispersed females.

If the development of sex-linked physical characteristics can be influenced by the social environment, it stands to reason that sex-linked behavior can be, too. One striking example comes from the previously mentioned female katydids, which compete for the males that bring them both sperm and food, in line with the Bateman-Trivers principles. Remarkably, when their environment becomes rich with nutritious pollen, their competitive "nature" wanes.

The environment is similarly important for adaptive behavior in mammals. Research published starting in the late 1970s found that rat mothers care for male and female pups differently. The males get licked more than the females in the anogenital region because the mothers are attracted to the higher level of testosterone in male pups' urine. Intriguingly, the greater stimulation from this higher-intensity licking plays a part in the development of sex differences in parts of the brain involved in basic masculine mating behavior.

As University of Sydney philosopher of science Paul Griffiths has observed, we should not be surprised that environmental factors or experiences that reliably recur every generation should be incorporated as inputs into the developmental processes that bring about evolved traits.

In our own species, these developmental inputs include the rich cultural inheritance bestowed on

MY ONE AND ONLY?

Although promiscuous mating has traditionally been viewed as a male trait that evolved to maximize male reproductive success, scientists have documented dozens of species across the animal kingdom in which

females have more offspring when they mate with multiple males.

every human newborn. And although social constructions of gender vary across time and place, all societies weight biological sex with heavy cultural meaning. Gender socialization starts at birth, and it would only make sense if the ruthless process of natural selection were to exploit it. It may well have been adaptive in our evolutionary past for males to take these and those risks or for females to avoid them. But when culture changes—creating a very different pattern of rewards, punishments, norms and consequences, compared with those in the past—so, too, will patterns of sex differences in behavior.

Thus, the *Economist* writer was not quite right in stating that human "mating preferences evolved over millennia and will not change quickly." True, they are unlikely to change as quickly as those of katydids, with a sprinkling of pollen (although we suspect that is not what was meant). There is usually nothing simple and quick about creating cultural shifts. But change certainly can, and certainly has, taken place over time-scales shorter than millennia.

Take, for example, gender gaps in the importance men and women place on a partner's financial resources, attractiveness and chastity. The very quaintness of the term "chastity" to Western ears today compared with several decades ago speaks to rapid changes in cultural gender expectations. Cross-culturally, women and men from countries with greater gender equity are more similar in all these dimensions of partner preferences than those from countries with lower equity between the sexes, according to a 2012 study by Marcel Zentner and Klaudia Mitura, both then at the University of York in England. Research has also shown that in the U.S., men now place more importance on a female partner's financial prospects, education and intelligence—and care less about her culinary and house-keeping skills—than they did several decades ago. Meanwhile the cliché of the pitiable bluestocking spinster is a historical relic: although wealthier and better-educated women were once *less* likely to marry, now they are more likely to do so.

Could we, then, see the day when the world's finest art galleries display as much art by women as by men? We certainly shouldn't let Bateman's fruit flies tell us no. ■

MORE TO EXPLORE

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IS THERE A “FEMALE” BRAIN?

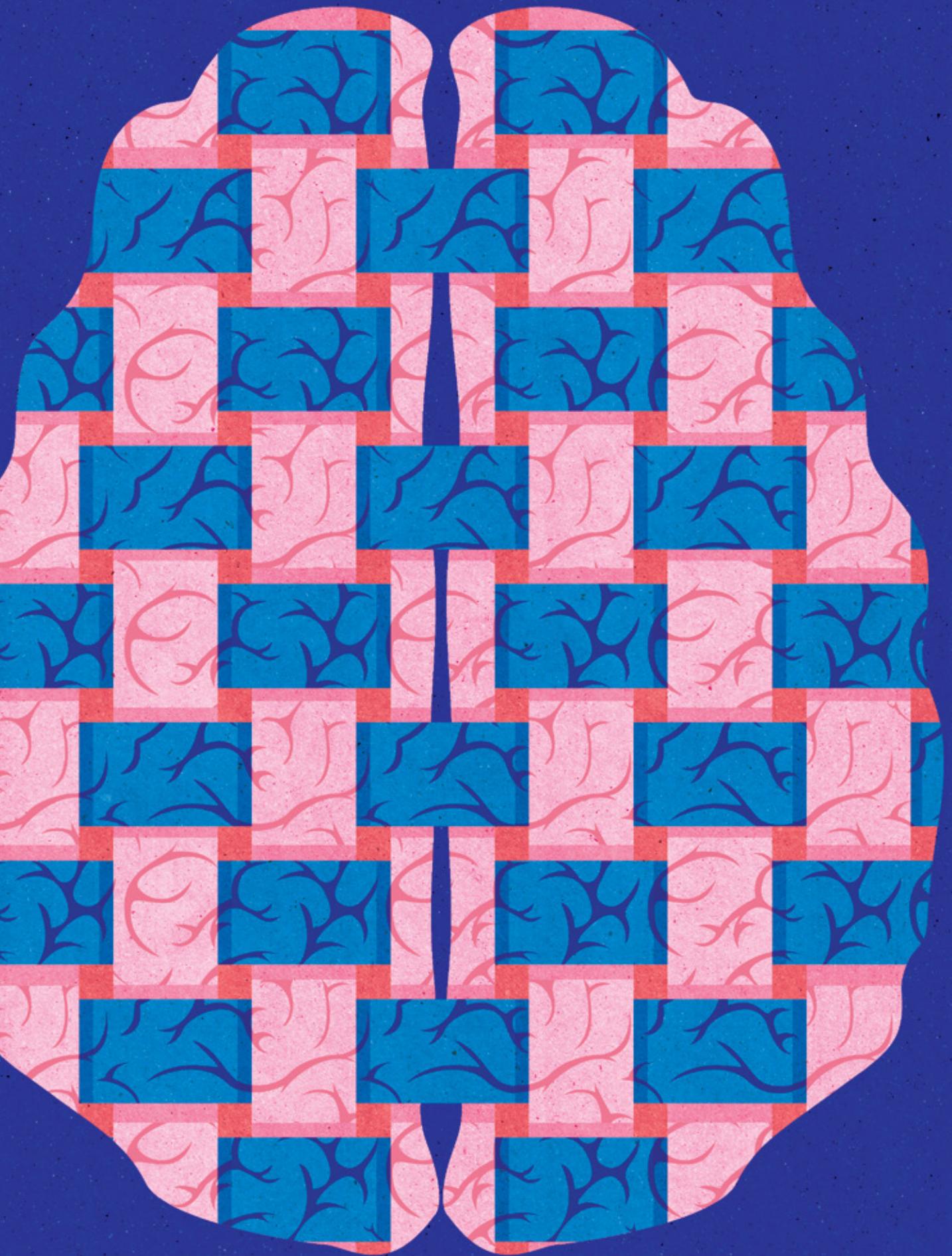
The debate over whether men and women have meaningfully different brains could have profound implications for health and personal identity

BY LYDIA DENWORTH



IN 2009 DAPHNA JOEL, A NEUROSCIENTIST AT TEL AVIV University, decided to teach a course on the psychology of gender. As a feminist, she had long been interested in questions of sex and gender, but as a scientist, her research had been mostly on the neural underpinnings of obsessive-compulsive behavior. To prepare for the class, Joel spent a year reviewing much of the extensive and polarized literature on sex differences in the brain. The hundreds of papers covered everything from variations in the size of specific anatomical structures in rats to the possible roots of male aggression and female empathy in humans. At the outset, Joel shared a popularly held assumption: just as sex differences nearly always produce two different reproductive systems, they would also produce two different forms of brains—one female, the other male.

As she continued reading, Joel came across a paper contradicting that idea. The study, published in 2001 by Tracey Shors and her colleagues at Rutgers University, concerned a detail of the rat brain: tiny protrusions





Lydia Denworth is a Brooklyn, N.Y.-based science writer and author of *I Can Hear You Whisper: An Intimate Journey through the Science of Sound and Language* (Dutton, 2014). She is working on a book about the science of social behavior.

on brain cells, called dendritic spines, that regulate transmission of electrical signals. The researchers showed that when estrogen levels were elevated, female rats had more dendritic spines than males did. Shors also found that when male and female rats were subjected to the acutely stressful event of having their tail shocked, their brain responded in opposite ways: males grew more spines; females ended up with fewer.

From this unexpected finding, Joel developed a hypothesis about sex differences in the brain that has stirred up new controversy in a field already steeped in it. Instead of contemplating brain areas that differ between females and males, she suggested that we should consider our brain as a “mosaic” (repurposing a term that had been used by others), arranged from an assortment of variable, sometimes changeable, masculine and feminine features. That variability itself and the behavioral overlap between the sexes—aggressive females and empathetic males and even men and women who display both traits—suggest that brains cannot be lumped into one of two distinct, or dimorphic, categories. That three-pound mass lodged underneath the skull is neither male nor female, Joel says. With her colleagues at Tel Aviv, the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig, Germany, and the University of Zurich, Joel tested her idea by analyzing MRI brain scans of more than 1,400 brains and demonstrated that most of them did indeed contain both masculine and feminine characteristics. “We all belong to a single, highly heterogeneous population,” she says.

When Joel’s work was published in 2015 in the *Proceedings of the National Academy of Sciences USA*, like-minded scientists hailed it as a breakthrough. “The result is a major challenge to the entrenched misconceptions,” wrote Gina Rippon, a professor of cognitive neuroimaging at Aston University in England. “My

hope is it will be a game-changer for the 21st century.”

Longtime sex-difference researchers, meanwhile, disagreed strenuously, taking issue with Joel’s methodology and conclusions, as well as her overt feminism. “The paper is ideology masquerading as science,” says neurobiologist Larry Cahill of the University of California, Irvine, who argues that Joel’s statistical methods were “rigged” (albeit not necessarily consciously) to favor her hypothesis. Other criticisms were more measured. “There’s variability within individuals, and she shows that beautifully, but that doesn’t mean there are no regions of the brain that, on average, are going to be different in men versus women,” says neuroscientist Margaret M. McCarthy of the University of Maryland School of Medicine, who studies sex differences in rats.

Joel, for her part, agrees that genetics, hormones and environment do create sex differences in the brain. She even agrees that given enough information about specific features in any one brain, it is possible to guess, with a high degree of accuracy, whether that brain belongs to a female or a male. But what you cannot do, she points out, is the reverse: look at any one man or woman and predict the topography and molecular landscape of that individual’s brain or personality just because you know the person’s sex.

Controversial as her study is, the essence of what Joel is saying is true, says Catherine Dulac, a molecular biologist at Harvard University whose work in mice echoes Joel’s findings: “There is huge heterogeneity between individuals.” Acknowledging that fact has opened a new thread in the conversation about what it means to be male or female. For neuroscientists, it is no longer enough to ferret out sex differences in the brain. The debate now centers on the source, size and significance of those differences. It could have major implications for how sex and gender are considered inside and outside the laboratory—and it may have consequences

SOURCE: “SEX BEYOND THE GENITALIA: THE HUMAN BRAIN MOSAIC,” BY DAPHNA JOEL ET AL., IN PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES USA, VOL. 112, NO. 50, DECEMBER 15, 2015

IN BRIEF

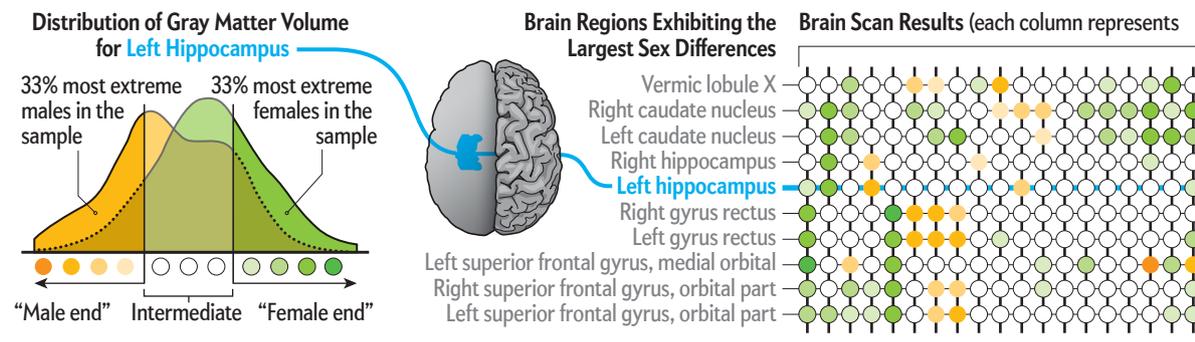
A popularly held assumption asserts that male and female brains are markedly different.

Controversial new research, however, suggests that most brains are a mosaic of male and female characteristics.

Ensuing debate has roiled neuroscience and raised questions about ways in which sex and gender are considered outside the laboratory.

The Mosaic Brain

Sex differences found in the human brain have led to the perception that brains are either male or female. A study by Daphna Joel of Tel Aviv University and her colleagues tells a different story. Joel’s research found that the typical brain is a “mosaic,” combining some features more common in males and some that appear more frequently in females, pointing to the conclusion that human brains do not belong to two distinct types categorized by sex.



as well for whether drug regimens and treatment protocols should be specialized for women and men. “Our entire society is built on the assumption that our genitals divide us into two groups not just in terms of reproduction ability or possibility but also in terms of our brain or behavioral or psychological characteristics,” Joel says. “People assume the differences add up. That if you are feminine in one characteristic, you will be feminine in other characteristics. But it’s not true. Most humans have a gender mosaic.”

CLAIMS AND COUNTERCLAIMS

IN THE LATE 1800S, long before MRI was a gleam in any scientist’s eye, the primary measurable difference in male and female brains was their weight (assessed postmortem, naturally). Because women’s brains were, on average, five ounces lighter than men’s, scientists declared that women must be less intelligent. As journalist Angela Saini recounts in *Inferior: How Science Got Women Wrong—and the New Research That’s Rewriting the Story*, women’s-rights advocate Helen Hamilton Gardener (a pseudonym) took on the experts of the day, arguing that the ratio of brain weight to body weight, or brain size to body size, had to be more relevant to intelligence than brain weight alone or “an elephant might out-think any of us.” Fittingly, Gardener left her own brain to science. It was found to be five ounces lighter than the average male brain, but it was the same weight as that of the eminent male scientist who had founded the brain collection at Cornell University where her brain was stored. (For the record, Gardener was on to something. “Once you correct for brain size, most of these sex differences disappear, or they become very small,” says Lise Eliot, a neuroscientist at the Chicago Medical School at Rosalind Franklin University of Medicine and Science.)

For much of the next century concrete sex differences

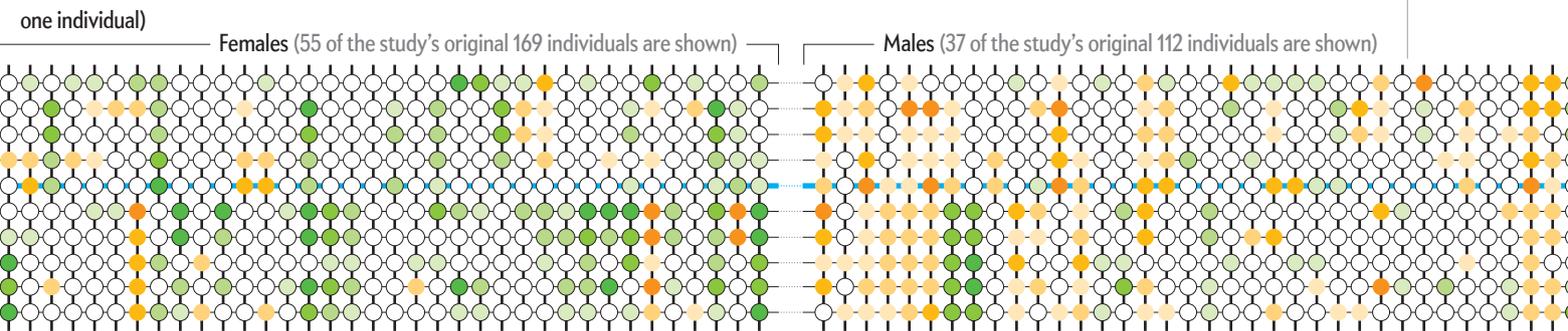
in the brain were the province not of neuroscientists but endocrinologists, who studied sex hormones and mating behavior. Sex determination is a complex process that begins when a combination of genes on the X and Y chromosomes act in utero, flipping the switch on feminization or masculinization. But beyond reproduction and distinguishing boy versus girl, reports persisted of psychological and cognitive sex differences. Between the 1960s and early 1980s Stanford University psychologist Eleanor Maccoby found fewer differences than assumed: girls had stronger verbal abilities than boys, whereas boys did better on spatial and mathematical tests. Predictably, critiques followed. Janet Hyde, a psychologist at the University of Wisconsin–Madison, has conducted meta-analyses, combining the results of previous studies, and found, as she wrote in a 2016 study, that females perform as well as males in math and that “males and females are quite similar on most—but not all—psychological variables.” Based on these results, Hyde developed what she calls the gender similarities hypothesis, which posits that the psychological makeup of men and women is more alike than different.

Once technology made it possible to peer inside a living brain, a long list of sex differences appeared that had nothing to do with mating or parenting. Writing in 2006 in *Nature Reviews Neuroscience*, Cahill described “a surge of findings from animals and humans concerning sex influences on many areas of brain and behaviour, including emotion, memory, vision, hearing, processing faces, pain perception, navigation, neurotransmitter levels, stress hormone action on the brain and disease states.” In rats, McCarthy measures everything from the size of the collections of neurons that make up cell nuclei to the number of astrocytes and microglia, cells that form a support system for neurons. “There’s irrefutable evidence of a biological basis for sex differences in the brain beginning from animals all the way

NEURAL SIGNATURES OF THE SEXES

In her 2015 study, Joel examined MRIs of more than 1,400 brains and found significant overlap among the areas of neural tissue (gray matter) showing the largest differences between males and females. In brain scans of the left hippocampus, most females and males had a volume of gray matter toward the middle on a continuum of “maleness” or “femaleness” (graph at left and white dots from a subset of the study data below). In addition, about a third of individuals

had features at both the maleness and femaleness extremes, shown below as green (femaleness) and orange (maleness) in dots of varying shades. Only 2.4 percent, meanwhile, had just features from one extreme. The trend was also reflected in the other data sets used by the researchers, and the findings were corroborated by a subsequent analysis of personality traits, attitudes and behaviors.



up to humans,” she says. But McCarthy also emphasizes that the source of sex differences in humans is more complicated than in animals that do not contend with gender, the psychological and social attributes of sex. “In humans, the fact that you’re raised as a particular gender from the instant that you’re born of itself exerts a biological impact on your brain,” she says. In her 2009 book *Pink Brain, Blue Brain*, Eliot agrees, arguing that plasticity, the way the brain changes in response to experience, drives sex differences in behavior more than hardwired biology does.

Making the leap from brain to behavior provokes the most strident disagreements. The most recent high-profile study accused of playing to stereotypes (and labeled “neurosexist”) was a 2014 paper by Ruben Gur, Raquel Gur and Ragini Verma, all at the University of Pennsylvania. The group used diffusion tensor imaging, a technique showing the strength of connections among neurons, to look at nearly 1,000 brains of subjects between the ages of eight and 22. It found that males had stronger connections within the left and right hemispheres of the brain and that females had more robust links between hemispheres. The researchers concluded that “the results suggest that male brains are structured to facilitate connectivity between perception and coordinated action, whereas female brains are designed to facilitate communication between analytical and intuitive processing modes.” (Counterclaim: the study did not correct for brain size.)

IN SEARCH OF VARIABILITY

INTO THIS MAELSTROM stepped Joel. Many previous studies have identified differences in single brain features and then used those differences to make claims about entire populations—the averages for women and men. Joel and her colleagues did the opposite: they used a picture of the population-level differences encountered across an entire group to ask what claims can be made about individual brains. “These are two different descriptions of the world,” Joel says. Both show the same group-level differences. The critical question is: Which better describes human brains—the first, in which one type of brain is typical of males and another of females, or the second, in which most people’s brains are mosaics of male and female characteristics?

Specifically, Joel’s 2015 study asked two questions: How much overlap is there in features that show differences between females and males? And are brains “internally consistent”? The latter is a measure Joel developed to determine if all features in any one brain were masculine or feminine. Using four large sets of MRI data, her team identified, in each data set, several features with the greatest difference between males and females, such as the collective volume of the nerve cells’ central bodies and dendritic extensions (gray matter) and their connecting fibers (white matter). They found a continuum of features. Definitive feminized and masculinized features occupied the extremes, and an intermediate zone exhibited a mix of attributes.



The researchers then assessed every brain in the data sets region by region and coded each feature [see box on preceding pages]. They reasoned that if brains are internally consistent, elements that show sex differences should reliably take on male or female forms. It followed that few brains should exist with both feminine and masculine traits. But between 23 to 53 percent of brains (depending on the data set) contained features from both ends of the spectrum. Brains that were internally consistent were rare—from 0 to 8 percent of those examined.

Joel cites arguments for the desirability of single-sex classrooms as a real-world example of why variability matters. “[Single-sex education] assumes that boys have one set of characteristics—for example, they are more active and have less patience—and girls have another set of characteristics. Therefore, we should separate them and treat each group differently. What we are showing is that although this is true at the group level, it’s not true at the individual level. You can’t divide students into a group that is very active, likes sports, is very good at mathematics, and doesn’t like poetry and another group that is the mirror image. There are very few kids like this.”

Most scientists find Joel’s work demonstrating variability convincing. “Daphna’s contribution was to show, individual by individual, the variability within gender,” Eliot says. “Nobody ever publishes [those] data.” But many find the measurement of internal consistency problematic. One response to Joel’s *PNAS* paper was from Marco Del Giudice of the University of New Mexico and his colleagues. They argued that the definition Joel and her colleagues used for internal consistency was so extreme as to be biologically implausible, if not impossible. To prove it, they reran Joel’s analysis using entirely different sets of biological variables—for example, comparing variability among facial features of three very different-looking monkey species. If Joel’s method were valid, Del Giudice rea-

soned, the monkeys should show clear (“internally consistent”) facial distinctions across species.

Despite notably varied appearances among the three species, the distinguishing facial features of any one monkey rarely resulted in internal consistency, as defined by Joel—hence, Cahill’s view that the study is “rigged.” (In response, Joel contends that while internal consistency in the monkeys was low, variability was nonexistent when assessing the separate species, whereas variability—a mosaic—was more prevalent than internal consistency in her study, “thus supporting our conclusions that brains of men and women are not distinct populations.”)

The debate comes down to which matters more: the average or the individuals within the population under study. The answer often depends on the question being asked. But researchers can and do look at the same evidence and draw different conclusions. “The human brain may be a mosaic, but it is one with predictable patterns,” wrote Avram Holmes of Yale University and his colleagues in response to Joel in 2015, and they believe those patterns demand statistical consideration. Biologist Anne Fausto-Sterling, a professor emerita of biology and gender development at Brown University and a critic of sex-difference research, has another perspective. “Talking about average differences is misleading if that’s all we do,” she says. “The brain is not a uniform entity that behaves as something male or something female, and it doesn’t behave the same way in all contexts. Daphna is trying to get at the complexities of what brains actually do and how they function.”

The implications of this controversy for science, especially clinical research aimed at treating disease, are considerable. Between 1997 and 2000, 10 drugs were withdrawn from the U.S. market because they carried side effects that were dangerous, even fatal. Eight of the 10 had greater health risks for women than for men. In 2013 the U.S. Food and Drug Administration reduced by half the prescription dosage of zolpidem, the generic name for Ambien, for women. After registering patients’ complaints about drowsy morning commutes, researchers had discovered that the drug was still present in some women’s bodies on waking. Here, too, counterclaims appear. Eliot and Sarah Richardson, a historian of science and gender at Harvard, suggest that much of the differences in zolpidem’s side effects could be accounted for by body weight disparities. Weight is not the whole story, because women’s higher body fat levels cause some drugs to metabolize more slowly, but precision in identifying the truly critical variables for drug dosing should be possible [see “Not Just for Men,” on page 52].

Partly in response to such concerns, starting in January 2016, the National Institutes of Health required that all preclinical research, the phase before testing in humans, must include female animals. Janine Clayton, director of the NIH Office of Research on Women’s Health, was careful to say, in explaining the new policy, that including both sexes in studies does not necessari-

HER BRAIN, HIS BRAIN

That there are distinct
“female”
and
“male”
brains

is rooted more
in popular
culture than
in the scientific
literature.

ly mean looking for sex differences. Many regard this directive as an important step. McCarthy points out that various neurological diseases or disorders with an early onset, such as attention-deficit/hyperactivity disorder and autism spectrum disorder, are more common in males, whereas those that appear later, such as depression and anxiety, are more common in females. “In the face of that, we are compelled to look at the brain as a biological organ that differs in males and females,” she says. “To not do it would be a travesty.” But Joel, Fausto-Sterling and others worry that the pendulum will swing too far. They argue for research that includes sex as a variable, with an even number of male and female subjects, but that recognizes in analyzing results that “male” and “female” categories may reflect variables that have nothing to do with sex.

More broadly, if this work is to change the way society thinks about sex and gender, it might begin with terminology. “It’s time to dump the word ‘dimorphism,’” Eliot says. “A dimorphic structure is an ovary versus a testis. A 2 percent difference in gray matter to white matter ratio is not dimorphic. It’s just a sex-related variance.”

Dulac argues that we need “a more refined way to define these differences.” In mice, she has found that neural circuits governing male mating behavior are also found in females, whereas maternal behavior circuits can be found in males. “It would be wrong to conclude from our work that there are no differences between males and females,” Dulac says. “But the very interesting question is: How are these differences emerging, and how subtle or significant are they?”

McCarthy and Joel joined forces earlier this year to lay out a more sophisticated framework for defining what is being measured in sex-difference research and what it means. They suggest four possible dimensions: whether a trait is persistent or transient; whether it depends on context; whether it takes only one of two forms—and is thus truly dimorphic—or else falls on a spectrum; and whether it is a direct or indirect consequence of sex. This way of describing the world of sex differences is not nearly as catchy as the long-standing Mars versus Venus metaphor, but it is probably much more accurate. As a rule, complexity more closely reflects who people really are. “My mother is very nurturing, but she’s a lot better at spatial navigation than my father,” Eliot says. “That’s a mosaic, right?” ■

MORE TO EXPLORE

Sex beyond the Genitalia: The Human Brain Mosaic. Daphna Joel et al. in *Proceedings of the National Academy of Sciences USA*, Vol. 112, No. 50, pages 15,468–15,473; December 15, 2015.

Incorporating Sex as a Biological Variable in Neuropsychiatric Research: Where Are We Now and Where Should We Be? Daphna Joel and Margaret M. McCarthy in *Neuropsychopharmacology*, Vol. 42, No. 2, pages 379–385; January 2017.

FROM OUR ARCHIVES

His Brain, Her Brain. Larry Cahill; May 2005.

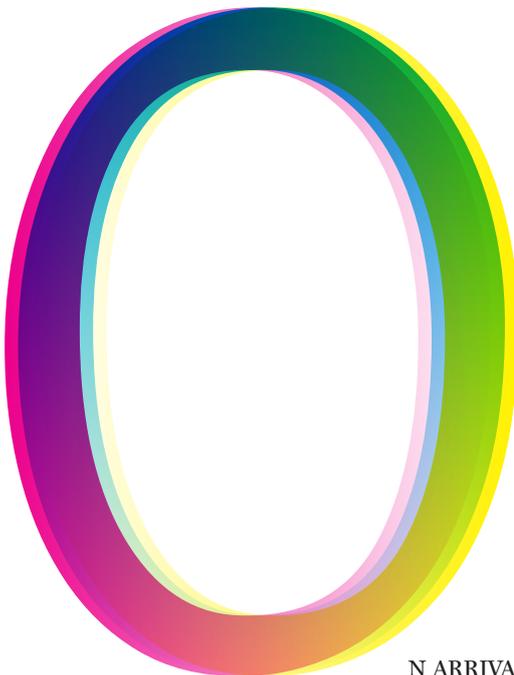
scientificamerican.com/magazine/sa



WHEN SEX AND GENDER COLLIDE

Studies of transgender kids are revealing fascinating insights about gender in the brain. Many trans children show surprisingly firm identities at young ages, for instance, and important differences divide trans girls from boys who like pink

BY KRISTINA R. OLSON



ON ARRIVAL AT A FRIEND'S HOUSE FOR DINNER one night in the fall of 2008, I joined the evening's youngest guest, five-year-old Noah, who was playing on the couch. Little did I know he would single-handedly change the course of my career.

As a professor of developmental psychology, hanging out at the kids' table is not unusual for me. I study how children think about themselves and the people around them, and some of my



keenest insights have come from conversations like this one. After some small talk, I saw Noah glance around the room, appear to notice that no one was looking and retrieve something from inside his pocket. The reveal was slow but the result unmistakable: a beloved set of Polly Pocket dolls.

Over the next few years I got to know Noah well and learned more about his past (all names of children here are pseudonyms to protect their privacy). Noah's parents had first noticed that he was different from his brother in the preschool years. He preferred female playmates and toys more commonly associated with girls, but his parents were unfazed. As he got older, Noah grew out his previously short hair and replaced his fairly gender-neutral wardrobe with one that prominently featured Twinkle Toes—shoes that lit up in pink as he stepped. Unlike many similar kids, Noah's family, friends and school fully accepted him. They even encouraged him to meet other kids like himself, boys who flouted gender norms. Along with the other adults in Noah's life, I couldn't help but wonder: What did Noah's behavior mean? Was he gay? Could he just be a kid who paid less attention to gender norms than most? At the time I had no idea that these questions would soon guide my scientific research.

Life for Noah started to change when he hit third and fourth grade. Noah recently explained how at this time, it became increasingly apparent that although people accepted his preferences and befriended him nonetheless, the way he saw himself—as a girl—was at odds with the way others saw him. When people used his name and male pronouns, he realized that they thought of him as a boy. Noah remembers that this awareness made him increasingly unhappy—a feeling that had been rare just a few years earlier. According to his mom, previously cheerful and high-spirited Noah became sad and melancholy. This is when his family, after consulting with local therapists, reached a big decision that had been in the making for years. Noah

IN BRIEF

The TransYouth Project is an ongoing research study following more than 300 transgender and gender-nonconforming kids for 20 years to learn how their gender identity develops.

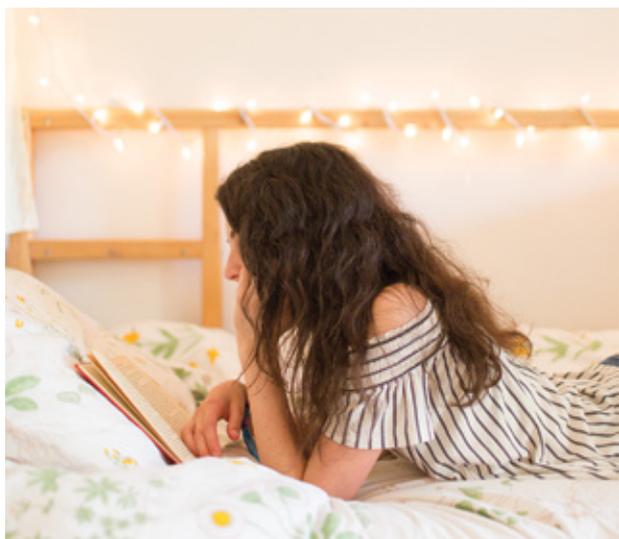
Results so far show that trans children have just as firm a sense of their own gender as nontrans kids at very early ages, both when asked directly and when tested. Furthermore, trans kids follow different trajectories than children who simply prefer toys and clothes associated with the opposite gender.

In addition to helping uncover the roots of gender, early results of these studies suggest that trans kids who are supported through early social transitions have strong mental health and self-esteem.



came out as transgender, and accordingly Noah's friends, family and school community were asked to use a new name, Sarah, and to refer to Sarah as a girl.

At this point I had been studying developmental psychology for a decade, mostly looking into how young children think about the social categories—race, gender, social class—around them. In my free time, I looked for research about kids such as Sarah. Not a single quantitative study had investigated young children who had “switched” gender. (“Sex” refers to the biological categories male and female, whereas “gender” references one's identification with the social and cultural attributes and categories traditionally attached to each sex.) At that time nearly all adults who were transgender had transitioned much later in life, and almost no one had supported their early gender nonconformity (their desire to express preferences or behaviors that defy societal expectations for their sex). I wondered what we could learn about gender from such young pioneers as Sarah. What was the impact of transition-



FOURTEEN-YEAR-OLD SARAH, photographed at home, knew from a young age that she was a girl rather than the boy she seemed to be at birth.

ing on children's mental health and identity? What would this decision mean for their future?

HOW WE LEARN GENDER

WHEN MOST PEOPLE HEAR about trans children, they are surprised. How could a three-year-old have such a clear sense of gender identity? People frequently compare early-identifying trans children with those who go through phases of believing they are cats or dinosaurs or who have imaginary friends. They use this comparison as evidence that no young child *knows* his or her identity or what is real or not real. Yet decades of work on gender development suggests these are precisely the ages at which nearly all kids are coming to understand their own and others' gender identities.

In Western cultures (where most of this research has been done), within the first year of life infants begin to distinguish people by sex, seeing individuals as either male or female. By about 18 months toddlers begin to understand gendered words such as "girl" or "man" and associate those words with sex-matched faces. By 24 months children know of sex stereotypes (such as associating women with lipstick), and before their third birthday nearly all kids label themselves and others with gender labels that match their sex.

During the preschool years, large numbers of young people go through what gender researchers May Ling Halim of California State University, Long Beach, and Diane Ruble of New York University call the "pink frilly dress stage": most girls become obsessed with frilly princess dresses or similarly "gendered" clothing, whereas many boys prefer superhero gear or formal wear and actively avoid pink. Around this time children also often exhibit strong preferences for the company of same-sex friends, engage in activities stereotypically associated with their sex and show a developing understanding that their sex is an enduring quality—believing that girls develop into women and boys into men.

Through the elementary school years, most chil-

dren continue to associate themselves strongly with their sex group when asked both directly and indirectly. One experiment involves asking young participants to sort photographs of children on a computer screen into "boys" and "girls" while categorizing a set of words as either "me" words (like "me" and "myself") or "not me" words (like "they" and "them"). Researchers measure how quickly kids can make these categorizations when "boys" and "me" share one response key and "girls" and "not me" share another, compared with how quickly they can make the opposite pairings ("girls" with "me" and "boys" with "not me"). Past studies have found that an overwhelming majority of girls are faster at pairing "girls" with "me" and boys are faster at pairing "boys" with "me." Although scientists debate which aspects of development are innate or culturally constructed, or a combination of both, and not every child goes through the same gender pathway, most—including those children raised in families who vary in their parenting style, political beliefs, and racial and ethnic group membership—show the pattern we have described. And most parents, teachers and other adults never give it a second thought—except when kids start asserting that their gender is not what others expect it to be.

EARLY DIFFERENCES

WHEN I BEGAN the TransYouth Project in 2013, I wanted to understand whether, when and why young people such as Sarah do and do not behave like their peers in terms of their early gender development. The TransYouth Project is an ongoing study of hundreds of transgender and gender-nonconforming children. We focus on kids in the U.S. and Canada who are three to 12 years old when they begin the study, and we plan to follow them for 20 years.

What has been most surprising to me about our findings so far are the myriad ways in which trans kids' early gender development is remarkably similar to that of their peers. That is, children like Sarah look like other girls at every age but nothing like boys on measures of gender identity and preferences. Similarly, transgender boys (children who identify as boys but at birth were considered to be girls) perform like other boys on our tests. For example, one common observation in the preschool years is a strong hypergendered appearance—girls who *love* princess dresses; boys who avoid pink like it's the plague. We find the same thing in our youngest transgender children. The degree of their preferences for stereotypical clothes, as well as their tendency to prefer to befriend those of their self-identified gender and the degree to which they see themselves as members of their gender group, is statistically indistinguishable from their peers' responses on the same measures throughout the childhood years.

Furthermore, when predicting their identities into the future, trans girls see themselves becoming women and trans boys feel that they will be men, just as other girls and boys do. Even when we present children with more indirect or implicit measures of gender identity—



Kristina R. Olson is director of the TransYouth Project, which is supported by the National Science Foundation. She is an associate professor of psychology at the University of Washington.

the measures that assess reaction times rather than children's more explicit words and actions—we have found that trans girls see themselves as girls and trans boys see themselves as boys, suggesting that these identities are held at lower levels of conscious awareness. All this research combines to show that transgender identities in even very young children are surprisingly solid and consistent across measures, contradicting popular beliefs that such feelings are fleeting or that children are simply pretending to be the opposite gender.

THE ROOTS OF GENDER

BUT WHERE DOES THE FEELING of gender come from in the first place? The science is still far from conclusive. Because of how early this sense of identity can emerge, researchers have been looking for genetic and neuro-anatomical signs in transgender people. One approach scientists often use in studying genetics is to look at twins. A major difference between identical and fraternal twins is that the former share more of their genetic material than the latter. If researchers find more agreement in transgender identity among identical twins than in fraternal twins, they infer that genetics play some role. And in fact, this is exactly what early studies are finding (although identical twins may also share more aspects of their socialization and environment). For example, in one 2012 review of the literature, Gunter Heylens of Ghent University in Belgium and his colleagues looked at 44 sets of same-sex twins in which at least one twin identified as transgender. They found that in nine of the 23 identical twin pairs, both siblings were transgender, whereas in no case among the 21 same-sex fraternal twin pairs were both twins transgender, suggesting transgender identity has some genetic underpinning. Despite these results, however, which particular genetic variations are involved is an open question.

Similarly, although some neuroscience studies have shown that brain structures of trans people resemble those of individuals with the same gender identity, rather than people with the same sex at birth, these findings have often involved small samples and have not yet been replicated. Further complicating interpretation of neuroscience results is the fact that brains change in response to experience, so even when differences appear, scientists do not know whether structural or functional brain differences *cause* the experience of a particular gender identity or *reflect* the experience of gender identity. Muddying the already murky waters, neuroscientists continue to debate whether even among people who are not transgender, there are reliable sex (or gender) differences in brains [see “Is There a ‘Female’ Brain?” on page 38]. Thus, whereas the topic is an active line of work in many research laboratories around the world, definitive conclusions about genetic and neural correlates of gender identity remain elusive.

Perhaps the most critical questions about transgender children, however, are about their well-being.



CHARLIE prefers clothes and toys associated with girls but identifies as a boy. He is pictured here at age 10.

Transgender adults and teens who did not go through the early social transition of kids such as Sarah and who were often rejected by peers and even their own families tend to have highly elevated rates of anxiety and depression. Estimates suggest that more than 40 percent of these largely unsupported trans teens and adults will attempt suicide. Many families like Sarah's report that these heartbreaking statistics are why they supported their children's early transitions.

My colleagues and I are finding—both in reports from parents and from kids themselves—that trans youth who make the social transition at a young age are doing remarkably well. They have depression rates comparable to their peers and only slightly elevated rates of anxiety. They also show very strong self-esteem. Whether these indicators of mental health stay strong as our cohort of trans children moves into the teen years remains to be seen, and certainly our all-volunteer sample is unlikely to be fully representative of all trans children alive today. Yet paired with work suggesting that interventions in adolescence (that involve not only social transitions but also hormonal therapy) are associated with improved mental health, these findings suggest that the high rates of depression, anxiety and suicide seen in earlier studies are not inevitable. Instead, as the world becomes more educated about transgender people, as rejection and bullying decrease, and as these youth receive support and intervention at earlier ages, we are optimistic that mental health risks will decrease.

“PINK BOYS” AND TOMBOYS

THE FIRST QUESTION I typically get when talking about transgender kids is something like, “Are you saying tomboys are actually transgender?” or “I used to be a boy who loved princess dresses. Are you suggesting I was transgender?” Of course, not all children who defy sex stereotypes as Sarah did are transgender. In



SARAH'S DECISION to transition genders was made in elementary school. Sarah is shown with her parents here.

fact, I would venture to say that most of them are not.

One such kid is Charlie. On the surface Charlie seemed a lot like Sarah early in life. Both were assumed to be boys at birth, and both showed signs by the preschool years that they were different. As with Sarah, Charlie loved all things feminine. His mom recalls that by age two, Charlie loved pink sparkly clothing and would put a towel over his head pretending it was hair. Much like Sarah's family, Charlie's family introduced him to other boys who loved feminine stuff. And over the years some of these children, like Sarah, socially transitioned. But Charlie did not. I recently asked Charlie about his decision not to transition. He explained that his family (sometimes with the help of a therapist) spent a lot of time talking about social transitions and made it clear that they were onboard if that was what he wanted. Charlie said he considered this possibility in the back of his mind for several years but ultimately decided that although he unabashedly liked stereotypically "girl" things (in fact the very day I interviewed him, Charlie was wearing pink shorts, a purple T-shirt and a pink scarf to school) and even if he occasionally uses a girl's name at camp, at the end of the day Charlie feels that he is a boy. As his mom explained, Charlie said that what he really wanted was for the world to accept him as he is—to let him wear what he wanted to wear and do what he wanted to do. But he did not truly feel he was a girl.

My work with children such as Charlie is ongoing, but preliminary data from others suggest that distinctive developmental trajectories may differentiate Sarah and Charlie. For instance, the degree to which a child

gravitates to toys and clothes associated with the opposite gender may distinguish kids who ultimately identify as transgender from those who do not—on average, children like Sarah show even more gender nonconformity than children like Charlie. Other studies have suggested that the way kids talk about their gender identity—feeling you are a girl versus feeling that you wish the world was okay with your being a feminine boy (what Charlie's mom calls a "pink boy")—predicts the different paths of children like Sarah versus Charlie.

Researchers are also increasingly recognizing and studying people with nonbinary identities. Put simply, these are individuals who do not feel as if they are boys or girls, men or women, nor do they feel fully masculine or feminine. Instead many nonbinary people fall somewhere in the middle of a spectrum from masculine to feminine. To date, our research team has worked with several children who see themselves this way, but this group is not yet large enough from which to draw any strong conclusions.

What is undoubtedly true is that scientists have much to learn about children such as Sarah and Charlie. What does it mean to have a sense of yourself as a boy or a girl or something else? What makes a child more or less likely to identify that way? And how can we help all kids to be comfortable with themselves? Finding answers is especially difficult because gender is defined by culture, which constantly changes. In 1948, for instance, only 32 percent of adults believed women should wear slacks in public. Certainly feminine boys and masculine girls are not new; they are widely recognized in many indigenous cultures.

Today 14-year-old Sarah and 13-year-old Charlie are self-confident, smart and hardworking teens. Sarah plays piano, varsity field hockey and recently took up track. Charlie plays in a band and performs in theater. Both kids are popular and spend more of their time worrying about doing well in school and the complexities of adolescent social networks than about their gender. Both look to the future, excited about the possibilities that await them in college and beyond. Sarah says she wants to raise children with her future husband and aspires to make the world better for trans young people like herself. Charlie has dreams of moving to New York City to perform on Broadway. Both teens hope one day kids like them will be accepted for who they are regardless of the gender labels they use. In that hope, surely all of us can agree. ■

GENDERLESS BABY

In **2017**

Canada issued what may be the world's first genderless ID card to a baby born to a parent who preferred not to designate the child as either male or female.

MORE TO EXPLORE

Mental Health and Self-Worth in Socially Transitioned Transgender Youth. Lily Durwood et al. in *Journal of the Academy of Child and Adolescent Psychology*, Vol. 56, No. 2, pages 116–123.e2; February 2017. The TransYouth Project: <http://depts.washington.edu/transyp>

FROM OUR ARCHIVES

Transgender Kids: What Does It Take to Help Them Thrive? Francine Russo; *Scientific American Mind*, January 2016.

scientificamerican.com/magazine/sa

BEYOND XX AND XY

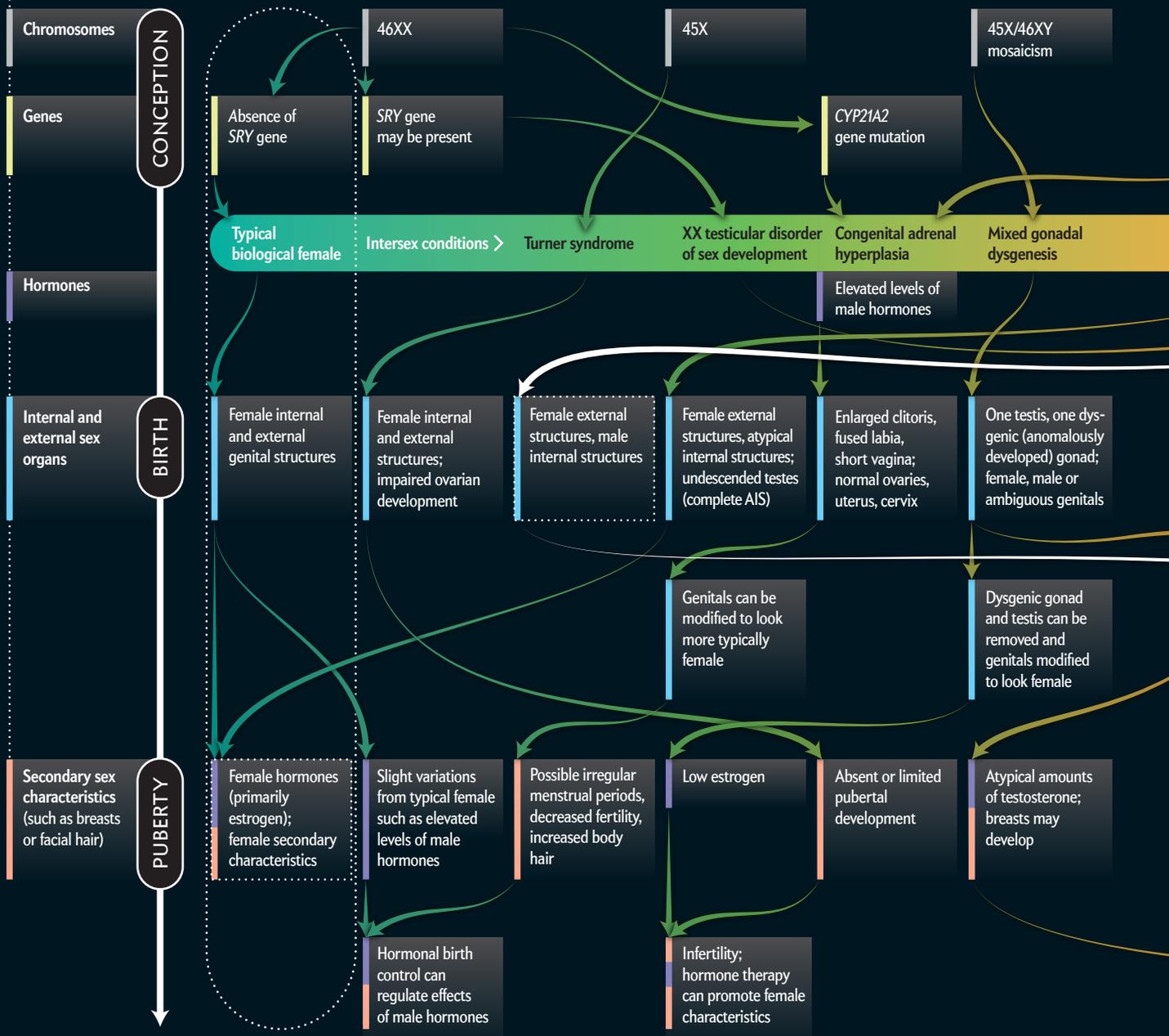
A host of factors figure into whether someone is female, male or somewhere in between

Humans are socially conditioned to view sex and gender as binary attributes. From the moment we are born—or even before—we are definitively labeled “boy” or “girl.” Yet science points to a much more ambiguous reality. Determination of biological sex is staggeringly complex, involving not only anatomy but an intricate choreography of genetic and chemical factors that unfolds over time. Intersex individuals—those for whom sexual development follows an atypical trajectory—are characterized by a diverse range of conditions, such as 5-alpha reductase deficiency (circled). A small cross section of these conditions and the pathways they follow is shown here. In an additional layer of complexity, the gender with which a person identifies does not always align with the sex they* are assigned at birth, and they may not be wholly male or female. The more we learn about sex and gender, the more these attributes appear to exist on a spectrum.

—Amanda Montañez

*The English language has long struggled with the lack of a widely recognized nongendered third-person singular pronoun. A singular form of “they” has grown in widespread acceptance, and many people who do not identify with a binary gender use it.

FACTORS THAT DETERMINE SEX



The Gender Spectrum

A transgender woman is a person who was assigned male at birth based on her anatomy but who identifies as a woman.

A cisgender woman is a person who was assigned female at birth based on her anatomy and who also identifies as a woman.

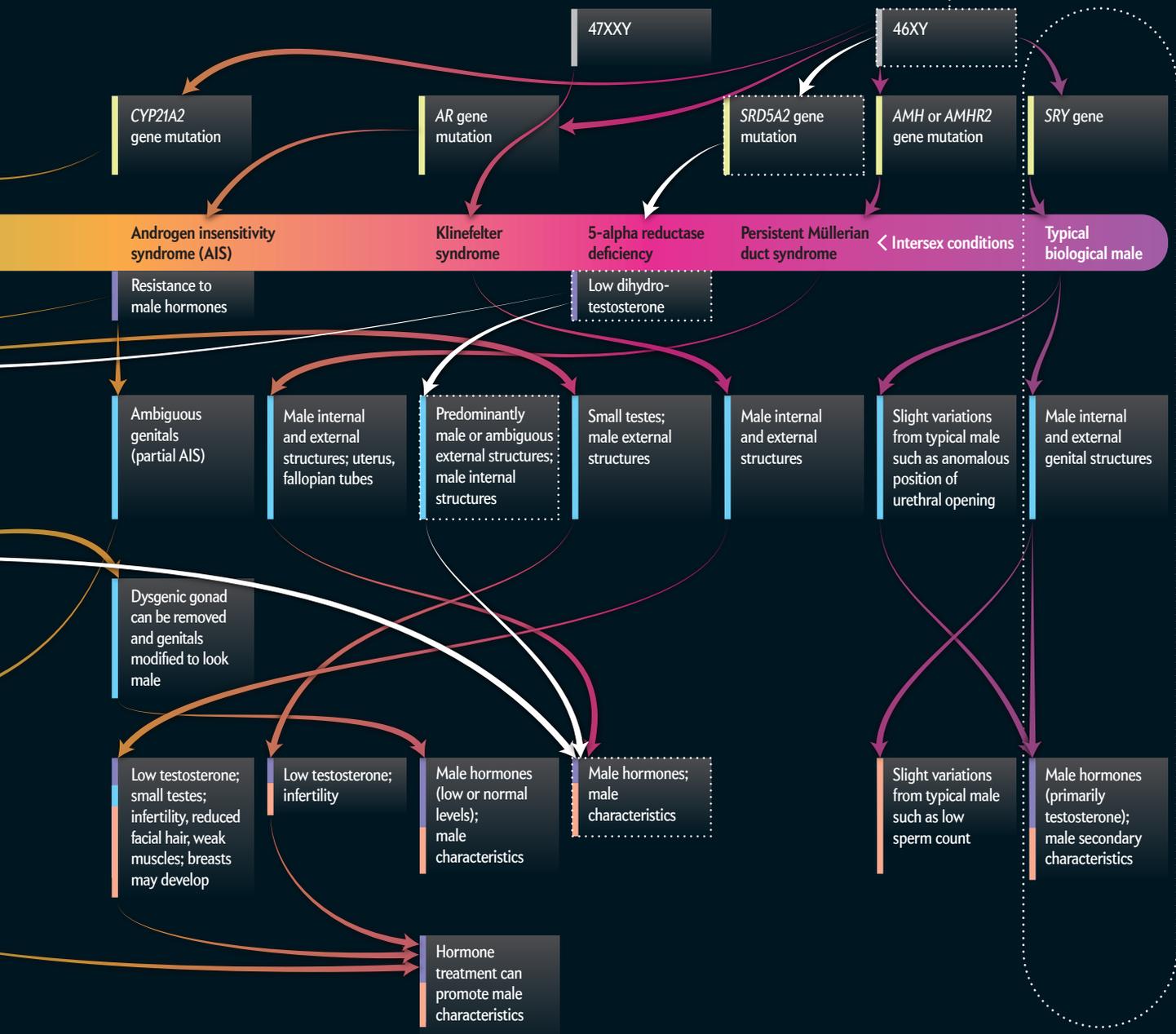
A nonbinary person is someone who identifies as neither completely female nor completely male. Such an individual may identify with both genders or neither gender, or they may be gender fluid, meaning their gender fluctuates between female and male.

A transgender man is a person who was assigned female at birth based on his anatomy but who identifies as a man.

A cisgender man is a person who was assigned male at birth based on his anatomy and who also identifies as a man.

5-alpha reductase deficiency is an intersex condition that can follow multiple pathways throughout development. Affected individuals have a chromosomal makeup of 46XY, like a typical biological male, but a genetic mutation causes a deficiency of the hormone dihydrotestosterone. Patients' external anatomy can vary, so an individual might be assigned to either sex at birth, but at puberty a surge of testosterone promotes male characteristics. As a result, patients who are raised as girls often end up identifying as male.

Sexuality refers to an individual's sexual orientation or to the kind of person to whom they are attracted. Sexuality is also a spectrum but is separate from both sex and gender.



NOT JUST FOR MEN

Researchers and doctors must dig deeper into gender differences before they can provide women with better treatments

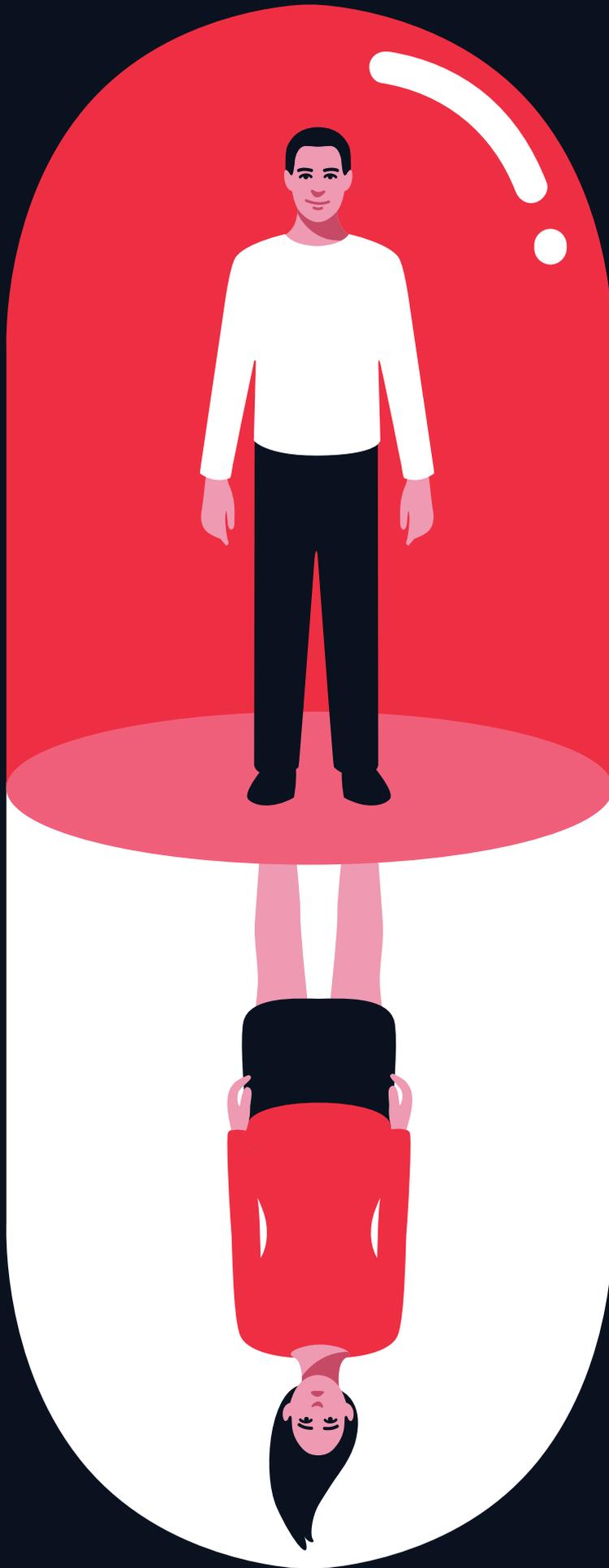
BY MARCIA L. STEFANICK

IN JANUARY 2013 THE U.S. FOOD AND DRUG ADMINISTRATION CUT THE recommended dose of the nation's most popular sleep drug, Ambien, in half for women but not for men. The FDA had determined that 15 percent of the 5.7 million American women using zolpidem products (the active ingredient in Ambien) were experiencing driving impairment eight hours after taking the drug, compared with 3 percent of the 3.5 million male zolpidem users.

Researchers had known for a long time that women, on average, clear zolpidem from their body much more slowly than men do. Indeed, drug metabolism, tolerance, side effects and benefits differ significantly between the average man and woman for many widely prescribed medications, with women having a 50 to 70 percent higher chance of an adverse reaction. Body size, proportion of fat to muscle and a host of other factors, including hormonal influences, account for these differences. But physicians rarely consider these dynamics when writing prescriptions. Ambien, which now comes in bottles with pink (low dose) and blue (original dose) labels, is a rare example of a “sex-specific” medical recommendation.

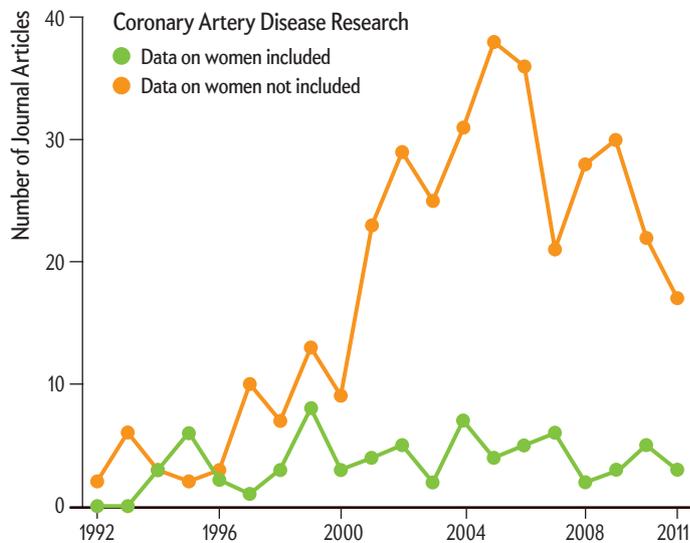
Drug-dosing problems are just one example of how the health care system is blind to biological sex differences. As a result, women are too often treated like men. Moreover, the system can be blind to gender bias; some disorders are considered “a man’s” or “a woman’s,” even when both sexes suffer from them. Doctors often fail to diagnose stereotypical “male” conditions in women, and vice versa, until the condition has become dangerous.

These problems arise from a serious gap in our understanding of sex differences. The vast majority of animal research has been conducted only on males, mostly on rodents. And women have been grossly underrepresented in human clinical trials. Even when both sexes are included, sex-specific analyses are generally not reported—and because most subjects are men, the findings may not pertain to women. A 2003 review of 258



Research Bias

Medical studies often involve only male subjects or do not break out statistics for women if they are included. For example, a 2012 analysis of coronary artery disease therapies found that 355 of 427 journal articles (83 percent) either included no data for women or did not analyze data for women versus men. The paucity of research makes it difficult for doctors to assess treatments that could help women.



cardiovascular treatment trials, for example, revealed that only 27 percent of the participants were women and that only a third of the trials with men and women reported data by sex.

Not surprisingly, no one understood why a young woman hospitalized with a heart attack was twice as likely to die as a young man. Failure to include women in biomedical research was exacerbated by 1977 Food and Drug Administration guidelines that barred women of childbearing potential from participating in phase I (safety) and phase II (efficacy) trials, whether they were planning a pregnancy or not. Although the FDA now allows for inclusion of pregnant women in research that does not threaten pregnancy, few drugs are approved for pregnant women because safety and effectiveness data are not available.

FIXING THE PROBLEM

CHANGES IN PRACTICES have been long in coming. In 1990 scientists, advocates and members of Congress pushed the National Institutes of Health to establish the Office of Research on Women's Health. In 1991 the late cardiologist Bernadine Healy, the first and only woman director of the NIH, launched the Women's Health Initiative, which enrolled nearly 162,000 women across the U.S. The study led to important changes in clinical care; without it, for example, physicians might still be-

IN BRIEF

Doctors often assess women patients as if they were men because most medical research is based on male animals and men. This can lead to poor or dangerous therapies. **Physicians miss,** or improperly diagnose, heart disease in women because their symptoms differ from those men typically experience. Bias is widespread in screening for mental illnesses, too. **Progress is under way,** but mandates may be needed to ensure that female biology is properly, and widely, included in testing protocols, medical diagnoses and treatments.

lieve they should put most older women on hormone therapy, leading to many more heart attacks and strokes and cases of breast cancer. The 1993 NIH Revitalization Act required enrollment of female (and minority) participants in federally supported phase III trials—those designed to determine how a new treatment works in a large group. The act did not, however, require enrollment of enough women to determine how a given treatment affected women specifically.

More change came in 2001, when a landmark Institute of Medicine (IOM) report emphasized the important role that “sex” played in the basic biology that underpins health care. It concluded that “every cell has a sex.” Yet almost no cell biologists consider, or even know, the sex of the cells or tissues they study. Nor do they address how sex chromosomes affect the systems they are investigating. The IOM report defined sex as a biological quality or classification of sexually reproducing organisms, generally male or female, derived from chromosomes and sex hormones. Gender was defined, in human studies, as sociocultural—a person’s “self-representation as male or female.”

This concept can be expanded to include gender norms (social expectations of “masculine” and “feminine” behaviors) and gender relations (how people react to one another because of gender), all of which can exert powerful influences on biology. For example, men are generally stronger than women not only because of biological factors such as larger muscles but also because of gender roles: in many societies, men lift and carry most of the heavy objects. Another example might be the twofold greater incidence of (unipolar) depression in women, which may result from an interaction of biological and social factors, such as women being more likely to be sexually assaulted.

Since the IOM report, scientists, academicians and health policy advocates have been urging their institutions, journals and government agencies to confront the need to include women and female animals in research and to study sex differences. In 2009 the Gendered Innovations project at Stanford University engaged collaborators across the U.S., Canada and the European Union to develop practical methods for sex and gender analysis and to track progress on including sex and gender in research. In 2010 the Office of Research on Women's Health issued a strategic plan that identified the need to integrate sex and gender perspectives in basic science and medical research.

That same year the Canadian Institutes of Health Research went further and began asking grant applicants to indicate whether sex or gender was accounted for in their study proposals. Four years later a May 2014 notice in the journal *Nature*, written by NIH director Francis Collins and Janine Clayton, director of the Office of Research on Women's Health, unveiled policies designed to ensure that NIH-funded preclinical research consider both females and males, as well as the sex of cells. And in January 2016 the NIH began to require that sex as a biological variable be factored into

SOURCE: TREATMENT STRATEGIES FOR WOMEN WITH CORONARY ARTERY DISEASE: FUTURE RESEARCH NEEDS, BY ROWENA J. DOLORE ET AL. COMPARATIVE EFFECTIVENESS REVIEW NO. 66. AGENCY FOR HEALTHCARE RESEARCH AND QUALITY, DEPARTMENT OF HEALTH AND HUMAN SERVICES, AUGUST 2012

research designs, analyses and reporting. If grant applicants propose to study only one sex, they must present persuasive justification for doing so. In contrast to the Canadian Institutes, however, the NIH did not address the influence of gender on biology.

A MAN'S DISEASE

GENDER BIASES profoundly influence diagnoses and treatments and therefore health outcomes. Despite years of “Red Dress” campaigns, most people and many physicians still think of heart disease as a man's disease. They are surprised to learn that heart disease is the number-one killer of U.S. women, far exceeding deaths from breast cancer. Younger women, in particular, often go undiagnosed because physicians do not consider the possibility. Furthermore, women commonly report a range of symptoms beyond chest pain, which is the key complaint of men, including back pain, nausea, headache and dizziness. Physicians often refer to these as atypical symptoms because men do not report them.

In addition, although men and older women are likely to have a blockage in one or more of the coronary arteries from localized plaque—a buildup of cholesterol, fat and other substances—younger women are more likely to have diffuse plaque that lines and narrows the entire artery. Even though this leaves the heart muscle with an inadequate blood supply, no specific blockage is detected. A woman may be diagnosed as “free of heart disease” even though she is at high risk of a fatal heart attack. Fortunately, newer diagnostic tests can detect this nonobstructive disease, along with other issues more common for women. But for those tests to work, a physician has to consider the possibility that a young woman might have heart disease and order them. Research continues to reveal sex differences in risks and beneficial treatments, but prevention and treatment guidelines for women are still based predominantly on male data.

Pregnancy, now recognized as a major cardiovascular stress test, also contributes to sex disparities, yet researchers have only recently begun to realize the serious long-term consequences. Pregnancy-related hypertension and preeclampsia, as well as gestational diabetes (high blood glucose developed during pregnancy), increase a woman's chance of developing subsequent cardiovascular disease nearly twofold, as well as her risk of developing type II diabetes.

HARD TO DECIPHER

SEX DIFFERENCES and gender biases influence medical diagnoses and treatments for *everyone*. Osteoporosis, characterized by reduced bone strength, is considered a woman's disease because white women have twice the lifetime risk of fracturing a bone than white men do. Fracture prevention trials have included few men. Yet men account for nearly one in three hip fractures, and their medical outcomes are worse.

Men are more susceptible to viral, bacterial, para-

sitic and fungal infections than women are, although women have greater rates of sexually transmitted infections such as HIV and herpes simplex virus 2. On the other hand, the more robust immune system of women may explain why they constitute 70 percent of the 20 million Americans with autoimmune diseases, in which the immune system attacks one's own body tissues. Pregnancy may play a role here as well. Some fetal cells cross into the mother's blood and are found in her circulation decades later, and they have been implicated in some autoimmune diseases.

Sex and gender also shape neurological and mental diseases. Accumulating evidence suggests that the placenta of the male fetus responds to environmental stressors by promoting fetal growth, whereas the female placenta promotes gene and protein expressions that increase chances of survival. This difference may contribute to developmental disorders that are diagnosed more often in boys, such as autism and dyslexia—although diagnostic methods may overlook girls.

Gender bias surrounding mental illnesses seems to be widespread. The suggestion that boys and men manifest depression with anger, rather than withdrawal, may arise from a biased expectation that males externalize behaviors and females internalize them. Some mental health professionals around the world still assign certain symptoms almost exclusively to women, such as being “hysterical,” whereas men are likely to be diagnosed as “antisocial.” These biases affect treatments and health outcomes.

Bias is rampant when it comes to the brain. Pop psychology loves the idea that men and women have different brains. Reports show that males have more cortical connections within each of the brain's two hemispheres, whereas women have more connections between the hemispheres. But the reports fail to mention that 86 to 88 percent of all these combined connections are similar—suggesting that male and female brains are more alike than different. Research also increasingly shows that any individual's brain development over a person's lifetime is greatly influenced by neuroplasticity—the ability of brain cells to rewire over time. If the daily experiences of boys and men differ markedly from those of girls and women, differences in brain structure and function should be expected [see “Is There a ‘Female’ Brain?” on page 38].

This complicated picture makes it difficult to pin down causes and treatments for brain illnesses. Two thirds of the more than five million Americans who have Alzheimer's disease are women, not only because many more women than men survive to age 65 but also because more women acquire the disease across all age groups. In aging female cells, abnormal pairing of maternal and paternal X chromosomes during cell division may play a role. In men, only the X (maternal) chromosome may survive cell division, and the Y chromosome may no longer be present. Sex certainly influences the disease's progression, and it should be investigated.

LOPSIDED SCIENCE

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The ratio of neuroscience studies that incorporate only male animals compared with ones that use just females. Animal research provides the underpinning for many psychoactive drugs.



Marcia L. Stefanik is a professor of medicine at the Stanford Prevention Research Center and a professor of obstetrics and gynecology at the Stanford University School of Medicine. She is also director of the Stanford Women and Sex Differences in Medicine Center and is conducting a large trial of older women related to heart disease prevention and healthy aging.

Note to Doctor: Women Are Not Men

Medical studies relied heavily on men or male animals in the past, which slowed progress in women's health care, according to the Institute of Medicine. Although researchers are finally improving the mix, women and female animals are still in the minority. Parity is needed because many illnesses affect women differently than men. Women often respond differently to treatments as well. Here is just a sample.

CANCER

Overall, cancer kills more men than women, but averages mask important sex differences in specific types of cancer. Recognizing disparities could prevent doctors from overlooking or misdiagnosing symptoms.

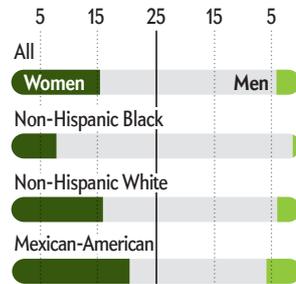
Women have a higher risk than men of developing right-sided colon cancer, a more aggressive killer than left-sided colon cancer. Diagnosis in women also tends to be more delayed.

More men than women die from lung, colon, kidney and liver cancer. But overall cancer risk is higher for women under age 50.

Being taller is a risk factor for many cancers in both men and women and may account for one third of the greater total cancer risk in men.

Side effects from fluorouracil, a common chemotherapy drug, are significantly worse in women; so are effects from many other cancer drugs.

Prevalence of Osteoporosis (percent of U.S. residents aged 50 and up, 2010)



BONES AND JOINTS

Sex and gender differences work both ways. White women are twice as likely as white men to have osteoporosis—fragile bones—but the risk of death from fragile-bone fractures is 50 percent greater for men.

Women undergo about two thirds of all knee replacements, but there is no evidence that “gender-specific” knees, marketed by manufacturers, improve outcomes. Overemphasizing sex differences can be a problem.

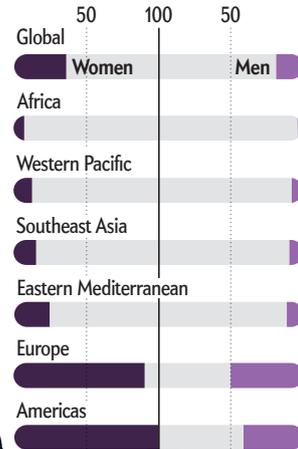
DISEASE

Certain thyroid autoimmune illnesses such as Hashimoto's disease and Graves' disease are 7 to 10 times higher in women; so is lupus.

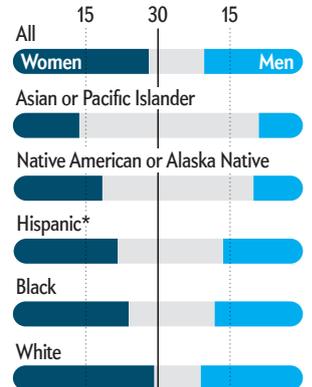
Rheumatoid arthritis, multiple sclerosis and scleroderma are at least 2 to 3 times higher in women.

More women than men are infected by herpes simplex virus 2.

Prevalence of Multiple Sclerosis (cases per 100,000 people, 2015)



Deaths from Alzheimer's Disease (age-adjusted deaths in U.S. per 100,000 people, 2014)



*Includes Hispanic black and Hispanic white

MENTAL ILLNESS

Twice as many women as men are diagnosed with anxiety or depression.

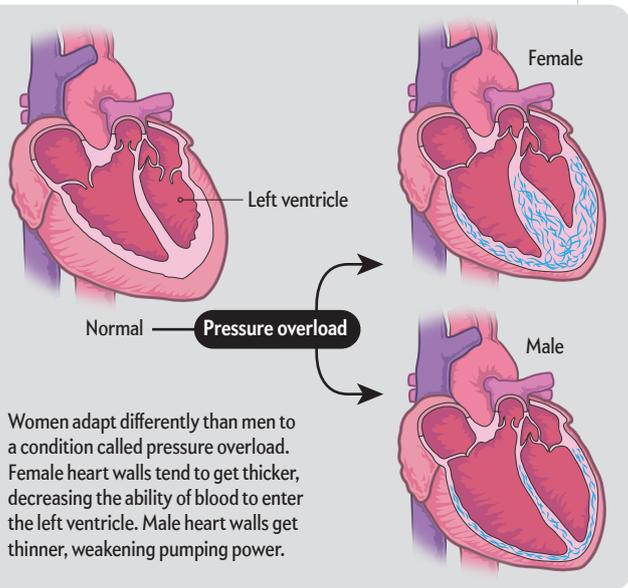
Almost two thirds of Americans with Alzheimer's disease are women. The APOE4 gene is more strongly linked to the disease in women. X and Y chromosomes may also play a role.

The number of older U.S. women dying of Alzheimer's is now greater than all U.S. women who die of breast cancer.



HEART PROBLEMS

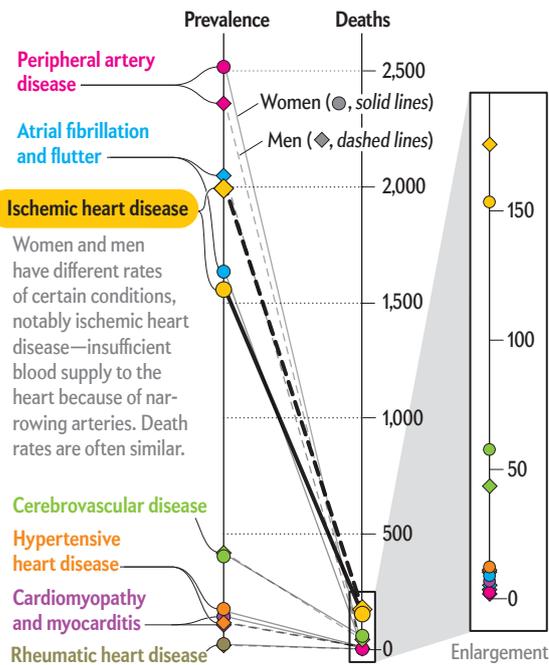
Heart complications often take different forms in women and men. Heart failure in women is more likely to result from left ventricle walls that stiffen and thicken (*illustration*). Among electrical problems, an irregular heartbeat is more common in men, while rapid heartbeat is more common in women—and certain drugs can make the condition life-threatening. Heart valve diseases vary, too. Blood clotting is greater in women, which can affect treatments; that trait may have evolved to prevent excess blood loss during childbirth.



SOURCES: "THE RECENT PREVALENCE OF OSTEOPOROSIS AND LOW BONE MASS IN THE UNITED STATES BASED ON BONE MINERAL DENSITY AT THE

FEMORAL NECK OR LUMBAR SPINE." BY NICOLE C. WRIGHT ET AL., IN *JOURNAL OF BONE AND MINERAL RESEARCH*, VOL. 29, NO. 11; NOVEMBER 2014 (osteoporosis); "GBD COMPARE." INSTITUTE FOR HEALTH METRICS AND EVALUATION, SEATTLE, WA. ACCESSED JULY 2017 <http://vizhub.healthdata.org/gbd-compare> (multiple sclerosis and heart disease); "DEATHS: FINAL DATA FOR 2014." BY KENNETH D. KOCHANEK ET AL., IN *NATIONAL VITAL STATISTICS REPORTS*, VOL. 65, NO. 4; JUNE 30, 2016 (Alzheimer's disease); "MECHANISTIC PATHWAYS OF SEX DIFFERENCES IN CARDIOVASCULAR DISEASE." BY YERA REGITZ-ZAGROSEK AND GEORGIOS KARARIGAS, IN *PHYSIOLOGICAL REVIEWS*, VOL. 97, NO. 1; JANUARY 2017 (heart illustrations)

Cardiovascular and Circulatory Disease (cases per 100,000 people in U.S., 2015)



TIME TO GET PERSONAL

CLEARLY, MEDICAL RESEARCHERS and physicians have a lot of untangling to do before they can offer better health care to women. A deeper understanding of sex differences will improve health directives for men, too. In 2015 the NIH launched a Precision Medicine Initiative to address the problem that most treatments have been designed for the “average patient” instead of each individual. “Precision” or “personalized” medicine is expected to take into account variability in genes, environment and lifestyle for each person. Yet genome-wide studies that try to pinpoint genetic variants that may be linked to specific diseases have generally excluded X and Y chromosomes, suggesting that sex is not an important focus of precision medicine.

The 2015 NIH mandate that researchers consider sex as a biological variable in animal and human studies provides promise. That same year the Canadian Institutes of Health Research rolled out an online training course on sex and gender in health research. And the League of European Research Universities released a report on how to integrate sex and gender into research processes. In October 2015 the Mayo Clinic hosted the Sex and Gender Medical Education Summit to tackle the serious problem that medical schools do not teach students about sex differences. The summit called for participants to create a road map for integrating sex- and gender-based evidence into medical education and to improve curricula within the next five years. In 2016 a panel of 13 experts representing nine countries developed the Sex and Gender Equity in Research guidelines, a comprehensive procedure for reporting sex and gender information in study design, data analyses, results and interpretation of findings.

These developments are encouraging. More is needed. We might need further mandates, through policy and funding restrictions, to ensure that female biology makes it into textbooks and testing protocols. We might also need to require best practices—standards of care that must be adhered to as part of the ethical code of “do no harm”—to ensure that clinicians and health care providers consider both sex and gender in medical diagnoses, screening and treatments. Both women and men would benefit enormously. Without sex and gender as a focus, physicians cannot achieve the precision medicine, specific to each one of us, that we all hope to receive. ■

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FROM OUR ARCHIVES

Hormone Hysteria? Dennis Watkins; October 2003.

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LIFE BEFORE ROE

Before 1973, abortion in the U.S. was severely restricted. More than 40 years later *Roe v. Wade* is under attack, and access increasingly depends on a woman's income or zip code

BY RACHEL BENSON GOLD AND MEGAN K. DONOVAN



WHEN SHE WENT BEFORE THE U.S.

Supreme Court for the first time in 1971, the 26-year-old Sarah Weddington became the youngest attorney to successfully argue a case before the nine justices—a distinction she still holds today.

Weddington was the attorney for Norma McCorvey, the pseudonymous “Jane Roe” of the 1973 *Roe v. Wade* decision that recognized the constitutional right to abortion—one of the most notable decisions ever handed down by the justices.

Weddington understood the ordeal many women faced when obtaining a clandestine procedure, although she kept that knowledge secret for decades. As she has subsequently written and talked about extensively, in 1967 Weddington (née Ragle) became pregnant when she was working three jobs and attending law school.

Without recourse to legal abortion in Texas, she and her partner drove from Austin across the border to a small building at the end of a series of dirt alleys in the town of Piedras Negras. Although Weddington was able to return to Austin and resume law school shortly after obtaining an abortion, the experience wiped out her meager savings. Many other women have told similar stories of pre-*Roe* abortions they, or someone they knew, experienced. For some women, especially those



Rachel Benson Gold is vice president for public policy at the Guttmacher Institute. Her work concentrates on delivery and financing of family-planning services.



Megan K. Donovan is a senior policy manager at the Guttmacher Institute, focusing on access to abortion and adolescent sexual and reproductive health care in the U.S. and internationally.

who were too poor, too young or otherwise unable to find a source of safe care, the clandestine procedure resulted in serious injury or even death.

The pre-*Roe* era is more than just a passing entry in the history books. More than 40 years after *Roe v. Wade*, antiabortion politicians at the state level have succeeded in re-creating a national landscape in which access to abortion depends on where a woman lives and the resources available to her. From 2011 to 2016 state governments enacted a stunning 338 abortion restrictions, and the onslaught continues with more than 50 new restrictions so far this year. At the federal level, the Trump administration and congressional leaders are openly hostile to abortion rights and access to reproductive health care more generally. This antagonism is currently reflected in an agenda that seeks to eliminate insurance coverage of abortion and roll back public funding for family-planning services nationwide.

Restrictions that make it more difficult for women to get an abortion infringe on their health and legal rights. But they do nothing to reduce unintended pregnancy, the main reason a woman seeks an abortion. As the pre-*Roe* era demonstrates, women will still seek the necessary means to end a pregnancy. Cutting off access to abortion care has a far greater impact on the options available and the type of care a woman receives than it does on whether or not she ends a pregnancy.

The history of abortion underscores the reality that the procedure has always been with us, whether or not it was against the law. At the nation's founding, abortion was generally permitted by states under common law. It only started becoming criminalized in the mid-1800s, although by 1900 almost every state had enacted a law declaring most abortions to be criminal offenses.

Yet despite what was on the books, abortion remained common because there were few effective ways to prevent unwanted pregnancies. Well into the 1960s, laws restricted or prohibited outright the sale and advertising of contraceptives, making it impossible for many women to obtain—or even know about—effective birth control. In the 1950s and 1960s between 200,000 and 1.2 million women underwent illegal abortions each year in the U.S., many in unsafe conditions. According to one estimate, extrapolating data from North Carolina to the nation as a whole, 699,000 illegal abortions occurred in the U.S. during 1955, and 829,000 illegal procedures were performed in 1967.

A stark indication of the risk in seeking abortion in the pre-*Roe* era was the death toll. As late as 1965, illegal abortion accounted for an estimated 17 percent of all officially reported pregnancy-related deaths—a total of about 200 in just that year. The actual number may have been much higher, but many deaths were officially attributed to other causes, perhaps to protect women and their families. (In contrast, four deaths resulted from complications of legally induced abortion in 2012 of a total of about one million procedures.)

The burden of injuries and deaths from unsafe abortion did not fall equally on everyone in the pre-*Roe* era.



Because abortion was legal under certain circumstances in some states, women of means were often able to navigate the system and obtain a legal abortion with help from their private physician. Between 1951 and 1962, 88 percent of legal abortions performed in New York City were for patients of private physicians rather than for women accessing public health services.

In contrast, many poor women and women of color had to go outside the system, often under dangerous and deadly circumstances. Low-income women in New York in the 1960s were more likely than affluent ones to be admitted to hospitals for complications following an illegal procedure. In a study of low-income women in New York from the same period, one in 10 said they had tried to terminate a pregnancy illegally.

State and federal laws were slow to catch up to this reality. It was only in 1967 that Colorado became the first state to reform its abortion law, permitting the procedure on grounds that included danger to the pregnant woman's life or health. By 1972, 13 states had similar statutes, and an additional four, including New York, had repealed their antiabortion laws completely. Then came *Roe v. Wade* in 1973—and the accompanying *Doe v. Bolton* decision—both of which affirmed abortion as a constitutional right.

The 2016 Supreme Court decision in *Whole Woman's Health v. Hellerstedt* reaffirmed a woman's constitutional right to abortion. But the future of *Roe* is under threat as a result of President Donald Trump's commitment to appointing justices to the Supreme Court who he says will eventually overturn *Roe*. Should that happen, 19 states already have laws on the books that could be used to restrict the legal status of abortion, and experts at the Center for Reproductive Rights estimate that the right to abortion could be at risk in as many as 33 states and the District of Columbia.

To be sure, abortion and the after care a woman receives have changed dramatically since the pre-*Roe* era. The alternatives outside a traditional medical set-

ABORTION-RIGHTS supporters and opponents stage rallies in front of the U.S. Supreme Court on June 20, 2016.

ting now available to women involve safer methods, including the use of drugs such as misoprostol for ending a pregnancy. Even so, the truth remains that restricting or banning abortion will not make it go away. These actions will perpetuate inequality because poor women and women of color are more likely than white or wealthy peers to be denied access to care and face legal penalties for seeking alternatives.

In light of state and federal policy makers' hostility to abortion, a commonsense policy goal would be to provide all women access to quality, affordable contraceptive care. In addition to respecting women's human rights and yielding significant health, social and economic benefits, this step would also lead to fewer unintended pregnancies. In 2014 the U.S. abortion rate reached its lowest level ever recorded, and strong evidence suggests that the steep drop in abortion between 2008 and 2014 was driven largely by improved contraceptive use. Notably, these declines happened in almost all 50 states, including those such as California and New York that are broadly supportive of abortion rights.

Good policy follows where the evidence leads. But the Trump administration and congressional leaders are moving in the opposite direction by pursuing plans that would undermine women's ability to obtain the contraceptive care they need. These attacks include attempts to roll back the many gains of the Affordable Care Act, gut Medicaid and undercut the critically important Title X national family-planning program, even while attacking Planned Parenthood, a trusted provider of contraceptive services for millions.

Instead of repeating the mistakes of the past, we need to protect and build on gains already made. Serious injury and death from abortion are rare today, but glaring injustices still exist. Stark racial, ethnic and income disparities persist in sexual and reproductive health outcomes. As of 2011, the unintended pregnancy rate among poor women was five times that of women with higher incomes, and the rate for black women was more than double that for whites. Abortion restrictions—including the discriminatory Hyde Amendment, which prohibits the use of federal dollars to cover abortion care for women insured through Medicaid—fall disproportionately on poor women and women of color.

These realities are indefensible from a moral and a public health standpoint. The time has come for sexual and reproductive health care to be a right for all, not a privilege for those who can afford it. ■

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Lessons from Before Roe: Will Past Be Prologue? Rachel Benson Gold in *Guttmacher Policy Review*, Vol. 6, No. 1, pages 8–11; March 2003.

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FROM OUR ARCHIVES

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scientificamerican.com/magazine/sa





THE BRILLIANCE TRAP

How a misplaced emphasis on genius subtly discourages women and African-Americans from certain academic fields

BY ANDREI CIMPIAN AND SARAH-JANE LESLIE

IN THE 1980S PHILOSOPHERS WOULD SOMETIMES SPEAK OF “THE BEAM”—a metaphorical spotlight of intellectual brilliance that could illuminate even the most complex philosophical conundrums. Only some lucky philosophers were ever born with the Beam, and their work represented the gold standard of the field. Anyone who lacked the Beam was forever condemned to trail behind them intellectually.

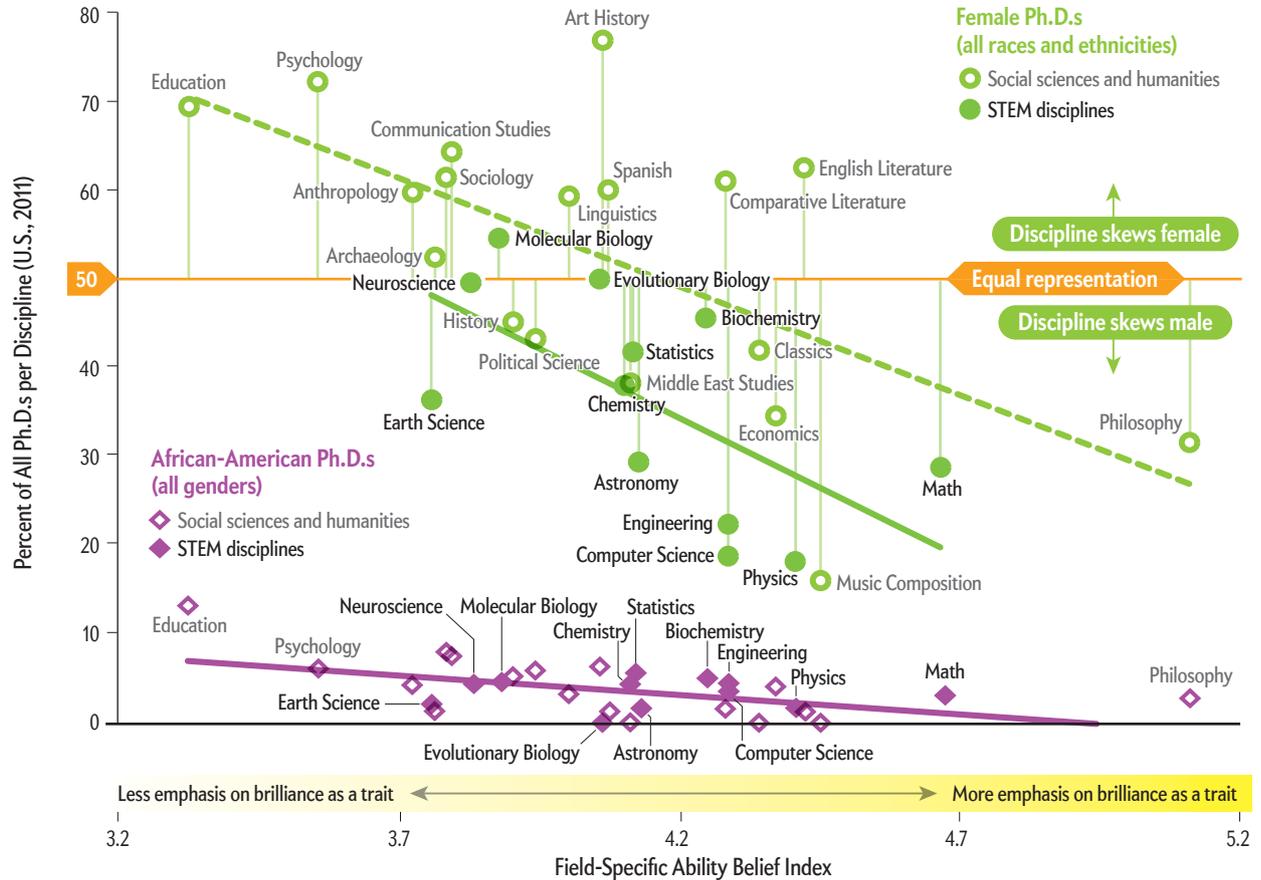
One of us (Leslie) would share this sort of story whenever we would see each other at conferences. The two of us were trained in different disciplines (Leslie in philosophy and Cimpian in psychology), but we studied similar topics, so we would get together regularly to catch up on research and talk about our experiences as members of our respective fields.

Psychology and philosophy are quite similar in their substance (in fact, psychology was a branch of philosophy until the mid-1800s), but the stories we told painted a picture of two fields with vastly different views on what is important for success. Much more so than psychologists, philosophers value a certain *kind of person*—the brilliant superstar with an exceptional

How Stereotypes about Genius Affect Women and Minorities in Academia

A survey of almost 2,000 professionals in 30 academic fields determined how strongly they believed that the trait of brilliance, as measured by a so-called field-specific ability belief index, mattered for success in their discipline. Fields with higher scores, such as

physics, math and philosophy, awarded fewer advanced degrees to women and African-Americans, compared with neuroscience and psychology, which scored lower. The results suggest that many fields implicitly equate brilliance with white males.



mind. Psychologists, in contrast, are relatively more likely to believe that the leading lights in their field grew to achieve their positions through hard work and experience.

At first, we viewed philosophy's obsession with brilliance as a quirk—a little strange but innocuous. Other things seemed like bigger problems in Leslie's field, such as its inability to attract women and minorities. Despite sustained attention to issues of underrepresentation in recent years and some efforts to alleviate it, women still accounted for less than 30 percent of the doctoral degrees granted in philosophy in 2015; African-Americans made up only 1 percent of philosophy Ph.D.s. The field of psychology, on the other hand, has been quite successful in attracting and retaining women (72 percent of newly minted Ph.D.s), and Afri-

can-Americans held 6 percent of its 2015 doctoral degrees, which admittedly still falls short of their share of the general population but is nonetheless six times the ratio in philosophy.

We could not wrap our minds around the discrepancy. Our fields have so much in common—both philosophers and psychologists ask questions about how people perceive and understand the world, how they decide between right and wrong, how they learn and use language, and so on. Even the few salient differences—such as psychologists' greater use of statistics and randomized experiments—are becoming blurred nowadays with the huge increase in the popularity of experimental philosophy, in which philosophers conduct surveys and experiments to explore different perspectives on morality, for example. How could

SOURCE: "EXPECTATIONS OF BRILLIANCE UNDERLIE GENDER DISTRIBUTIONS ACROSS ACADEMIC DISCIPLINES," BY SARAH-JANE LESLIE ET AL., IN SCIENCE, VOL. 347, JANUARY 16, 2015

two such closely related fields be so vastly different in membership?

A BRILLIANT IDEA

THE CLOSEST THING either of us has ever had to a eureka moment came several years ago when we connected two threads running through the anecdotes we had been sharing. We were having dinner with a group of philosophers and psychologists at a conference, and the conversation happened to turn, in quick succession, from philosophers' infatuation with brilliance to the gender gap in their field. This chance juxtaposition brought to mind for us a connection we had never considered before: maybe the premium philosophers place on brilliance is actually the reason why so few of their colleagues are women or minorities. We did not discount the benefits of brilliance. Rather we wondered whether genius was more easily overlooked in women and African-Americans. Could it be that insistence on the need for a keen intellect in a particular field was tantamount to hanging a "Keep Out" sign to discourage any newcomers who did not resemble that field's current members?

On the surface, an emphasis on brilliance does not favor one group over another; as far as scientists can tell, cognitive ability is not intrinsically tied to gender or race. Philosophers seek a certain quality of mind—regardless of whose mind it is. This seemingly logical preference quickly becomes problematic, however, in light of certain shared societal notions that incorrectly associate superior intellect with some groups—for example, white males—more than others.

Even among the academics present that night, one of the views expressed was that men and women just thought differently. Women were alleged to be more practical and anchored in reality, whereas men were more willing to engage in the kind of counterfactual, abstract reasoning that is viewed as a sign of philosophical brilliance. We started to wonder whether such stereotypes, which amount to equating brilliance with men, might well dissuade women from entering a field that holds this quality in high esteem. Moreover, current members of such a field might themselves hold different expectations about the prospects of men and women and might evaluate and encourage them differently as a result. The same logic extends to race: our country has a long history of portraying African-Americans as intellectually inferior, which is particularly likely to affect their participation in a field that focuses so single-mindedly on the quality of one's intellect. Considering these stereotyped attitudes, which are unsupported by science, philosophy's fascination with brilliance may have a real impact on its diversity.

Later that night the two of us talked about our insight. We speculated whether its implications extend beyond our home disciplines. Talk of brilliance is common in academia and—it seemed to us—quite common in fields that have similar issues with diversity such as science, technology, engineering or mathemat-



Andrei Cimpian is an associate professor of psychology at New York University.



Sarah-Jane Leslie is Class of 1943 Professor of Philosophy at Princeton University.

IN BRIEF

Academic fields that prize the brilliance of their members, the authors found, are likely to be less diverse in gender and racial makeup.

Although innate cognitive ability is not, as far as scientists can tell, tied to gender or race, it is psychologically easier to ascribe this trait to people from groups stereotypically assumed to be intelligent.

Women and African-Americans may subconsciously interpret a field's emphasis on brilliance as a subtle "Keep Out" sign that dissuades them from entering certain disciplines in the sciences and humanities.

ics. Might our anecdotal comparison of philosophy and psychology have something new to say about the underrepresentation of women and minorities in these disciplines?

The more we thought about it, the more we realized that our brilliance hypothesis might also explain some of the variability in gender and race gaps *among* different scientific fields. For example, women make up nearly 50 percent of doctoral degrees in biochemistry but just more than 30 percent of Ph.D.s in organic chemistry. The difference cannot easily be explained by the content of the fields, in which there is considerable overlap, or by their history—biochemistry emerged from organic chemistry at about the same time psychology separated out of philosophy as an independent discipline. We wondered whether the demographic differences between such sibling subjects, as well as more generally among scientific fields, could be explained in part by the extent to which they emphasize exceptional intellectual talent as the key to success.

SUCCESSFUL MINDSETS

OUR EARLY CONJECTURES quickly reminded us of the rich body of work developed by psychologist Carol Dweck of Stanford University. Dweck and her colleagues have shown that one's beliefs about ability matter greatly for one's ultimate success. A person who sees talent as a stable trait (a "fixed mindset" in Dweck's terminology) is motivated to show off this aptitude and avoid mistakes, which presumably reflect the limits of that gift. In contrast, a person who adopts a "growth mindset" sees his or her current capacity as a work in progress. In other words, ability is a malleable quantity that can usually be increased with more effort and better strategies. For a person with a growth mindset, mistakes are not an indictment but rather a valuable signal highlighting which of their skills need work.

Although Dweck initially studied mindsets in individuals, she and Mary Murphy, now at Indiana University Bloomington, recently suggested that organized groups of people, such as companies and clubs, may also hold these sorts of views. We took that idea a step further and considered whether they might permeate entire disciplines as well. The fascination with brilliance in philosophy and other areas could conceivably create an atmosphere in which displays of intellectual prowess are rewarded, and imperfections are to be avoided at all costs. In combination with the stereotypes suggesting that genius is unevenly distributed across groups, such a field-wide perspective could easily turn toxic for members of stereotyped groups, such as women or African-Americans. After all, it is easy to "see" imperfections and inadequacies in those people whom you expect to have them.

Several long phone conversations later, we had a tentative plan for putting our ideas to the test. We would contact academic professionals from across a wide range of disciplines and ask them whether they thought that some form of exceptional intellectual tal-

ent was necessary for success in their field. We would then look up statistics on the gender and racial/ethnic composition of the people obtaining Ph.D.s in these disciplines, which the National Science Foundation freely supplies on its Web site. If our hunch was correct, we should see that those disciplines that place more value on brilliance would tend to have fewer female and African-American Ph.D.s. This pattern should hold not just at the macro level—when comparing the hard sciences, for example, with the social sciences and the humanities—but also *within* these broad domains—for disciplines as similar as philosophy and psychology.

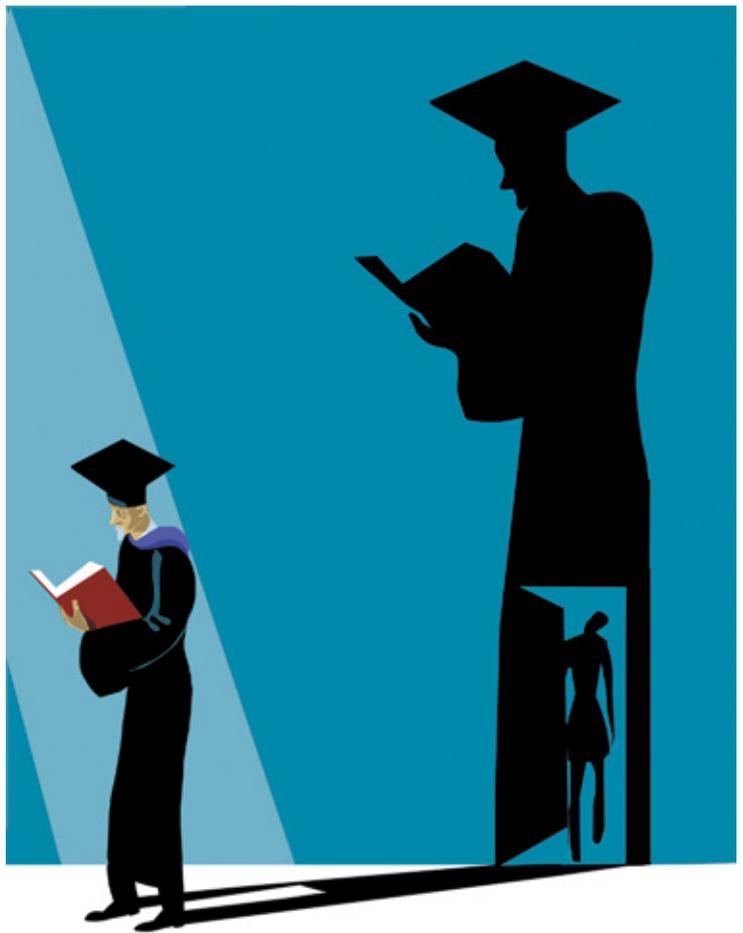
More than a year and thousands of e-mailed surveys later, we and our collaborators Meredith Meyer of Otterbein University in Ohio and Edward Freeland of Princeton University finally had an answer to some of our questions. Equal parts relieved and exhilarated, we saw that the answers received from almost 2,000 academics across 30 fields matched the distribution of Ph.D.s in the way we had expected. Fields that placed more value on brilliance also conferred fewer Ph.D.s on women and African-Americans. The greater the emphasis on this single fixed trait, the fewer doctoral degrees were awarded to either of these groups. The proportion of female and African-American Ph.D.s in psychology, for example, was higher than the parallel proportions for philosophy, math or physics.

Next, we separated the responses in the physical and biological sciences from those in the humanities and social sciences. Analyses of these subgroups indicated that a stronger emphasis on brilliance correlated with fewer female and African-American Ph.D.s regardless of whether we compared physics with biology or philosophy with sociology. It seemed that we had stumbled onto an explanation that was general enough to describe the representation of multiple stereotyped groups in fields across the entire academic spectrum.

ALTERNATIVE IDEAS

OUR EXCITEMENT ABOUT THESE DATA ASIDE, all we had really shown at this point was a correlation between the presumed desirability of a fixed trait—brilliance—with a dearth of women or African-Americans in a given field. We had not yet demonstrated cause and effect. Certainly many other plausible explanations for the gender imbalances have been proffered over the years—from a heavier workload that favored single men and those with wives who did not work outside the home to a supposed female preference for working with living organisms, as opposed to inanimate objects. We needed to determine whether we were bringing something new to the table—perhaps our explanation reduced to one that had been previously offered.

We carefully examined the most common alternatives. For instance, did our brilliance measure simply track differences between fields in their reliance on



math? We looked at the math portion of incoming students' Graduate Record Examinations (GREs) as a proxy. Beliefs about brilliance still predicted women's representation above and beyond those scores. Similarly, we found no support for the common view that women are underrepresented in "high-powered fields" because they prefer a better work-family balance. We asked the academics in our sample how many hours they worked per week—both on- and off-campus. Taking into account these differences in workload did not, however, reduce the explanatory power of beliefs about brilliance; this single variable still predicted the magnitude of gender gaps across the 30 disciplines. We also considered the prevalent thought that women might be more interested in working with (and have a better intuitive understanding of) people, whereas men prefer inanimate systems. But an analysis of the many branches of philosophy, for example, that do in fact consider people—and are still dominated by men—basically blew that idea out of contention.

As often happens in research, this initial study made it clear to us how much we did *not* yet know about the phenomenon we were investigating. For example, we realized it would be important to know if academics' beliefs about brilliance predict gender and race gaps

at earlier points in students' educational trajectories. We were very interested in testing our idea at the bachelor's level, which is the gateway to students' later careers. Do field-level messages about the importance of brilliance relate to the majors that young women and African-Americans ultimately pursue?

The answer to this question is yes, as we reported in *PLOS ONE* in 2016 when we analyzed anonymous student evaluations of their college instructors on RateMyProfessors.com. We found that undergraduates were nearly twice as likely to describe male professors as "brilliant" or a "genius" compared with female professors. In contrast, they used such terms as "excellent" or "amazing" equally often for men and women on the popular Web site. We determined that the overall amount of talk about brilliance and genius in the student reviews (which is a proxy for a field's emphasis on these qualities) correlated closely with a lack of diversity in completed majors.

ORIGINS OF STEREOTYPES

FURTHER INVESTIGATION SHOWED that nonacademics share similar notions of which fields require brilliance. Exposure to these ideas at home or school could discourage young members of stereotyped groups from pursuing certain careers (such as those in science or engineering) before they even set foot on a college campus.

At this point, we realized we needed to investigate the acquisition of these stereotypes. When do young people in our culture start thinking that some groups have more brilliant people in them? On the one hand, it could be that this stereotype emerges late in development, after sustained exposure to relevant cultural input (for example, media portrayals of brilliance and gender-biased expectations from parents, teachers, professors and peers). On the other hand, evidence from developmental psychology suggests that children are cultural sponges—incredibly sensitive to signals in their social environments. In fact, youngsters in the early elementary grades seem to have already absorbed the stereotypes that associate math with boys and reading with girls. From this perspective, we might expect that stereotypes about brilliance would also be acquired early in life.

To explore this idea, we asked hundreds of five-, six- and seven-year-old boys and girls many questions that measured whether they associated being "really, really smart" (our child-friendly translation of "brilliant") with their gender. The results, which we published in January in *Science*, were consistent with the literature on the early acquisition of gender stereotypes yet were still shocking to us. Male and female five-year-olds showed no difference in their self-assessment. But by age six, girls were less likely than boys to think that members of their gender are "really, really smart."

Finding these stereotypes so early in childhood made us ask whether they might already begin to constrain boys' and girls' interests. We introduced another group of five-, six- and seven-year-olds to

unfamiliar gamelike activities that we described as being "for children who are really, really smart." We then compared boys' and girls' interest in these activities at each age. The results revealed no gender differences at age five but significantly greater interest from boys at six and seven years of age—which is exactly where we saw the stereotypes emerge. In addition, the children's own stereotypes directly predicted their interest in these novel activities. The more a child associated brilliance with the opposite gender, the less interested he or she was in playing our games for "really, really smart children." This evidence suggests an early link between stereotypes about brilliance and children's aspirations. Over the rest of childhood development, this link may funnel many capable girls away from disciplines that our society perceives as being primarily for brilliant people.

The hard work of figuring out how best to put all this information to use—how to intervene—lies ahead of us. But a few suggestions follow pretty directly from the evidence we have so far. Minimizing talk of genius or brilliance with students and protégés may be a relatively easy and effective way of making one's field more welcoming for members of groups that are negatively stereotyped in this respect. Given current societal stereotypes, messages that portray this trait as singularly necessary may needlessly discourage talented members of stereotyped groups. The changes may need to go a little deeper than talk, however, and tackle some of the entrenched, systemic issues that accompany a field's fascination with brilliance. Refraining from mentioning the Beam will not help young women in philosophy if the rest of the field's practices continue to be implicitly anchored in the idea that brilliance is all that matters.

Another key takeaway is that we may need to intervene earlier than conventional wisdom suggests. Our developmental data indicate that some of the psychological processes that work against diversity in fields that value brilliance can be traced all the way back to elementary school. Waiting until college to step in and ensure that all young people have a fair shot at finding the careers that might suit them no longer seems like the best-timed intervention—we as a society would be wise to encourage a growth perspective, as opposed to a fixed-trait mindset, in young children as well. ■

FRIENDLY FIELDS

Of the 17,505 doctorates awarded in science and engineering to women in the U.S. in 2015,

40%
were given
in the
life sciences.

Of the 1,307 of such doctorates granted to African-Americans, more than

40%
were in
psychology
and the social
sciences.

MORE TO EXPLORE

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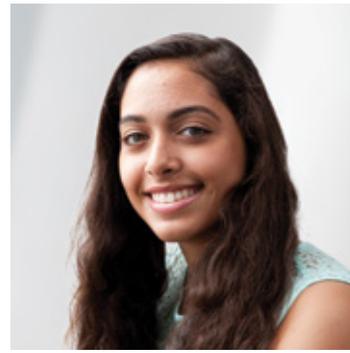
GIRL CODE

Early intervention is crucial to close the gender gap in computer science

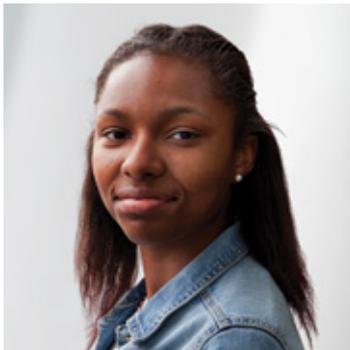
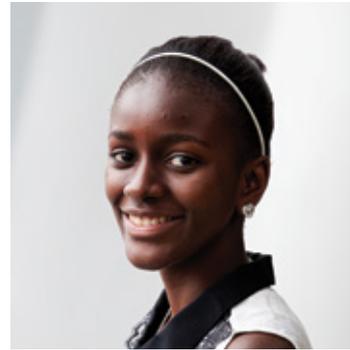
BY RESHMA SAUJANI



WHEN MY PARENTS CAME TO THE U.S. in 1973 as refugees from Uganda’s brutal dictator Idi Amin, we were one of the only South Asian families on my block in the suburbs of Chicago. As I grew up, my father wished for me to become one of three things: a doctor, a lawyer or an engineer like he was. To him, these were the jobs with the highest earning potential—jobs that could help our family rise up into the middle class. This was his idea of the “American dream.”



SMALL SAMPLE of the wide diversity among students who are enrolled in Girls Who Code programs.



IN BRIEF

The computing industry is one of the fastest-growing sectors of the U.S. economy, outpacing average national job growth by a factor of three.

Employers are struggling to fill available positions, in large part because so few women enter the field.

Boosting the numbers of women in computer science can help fill this gap and increase economic prosperity.

In 2002 I got my law degree from Yale University and eventually found work as a lawyer on Wall Street. But after years of dealing with securities fraud cases and asset management, I was ready for a change. So in 2010, at the age of 34, I quit my prestigious, high-paying job to run for Congress in New York City. While campaigning, I would visit hundreds

of classrooms across the district I hoped to represent. That district included some of the wealthiest and some of the poorest zip codes in the city, and in a single day I would visit schools with little to no access to computers, as well as ones with sophisticated computer labs and boys—almost always boys—clamoring along a new path to the American dream. In search

JESSICA GRANTON



of job security and prosperity, they were not studying to be doctors, or lawyers, or mechanical engineers—they were learning to code. Each time I walked out of one of these privileged classrooms, I would ask myself, “Where are the girls?”

Although I ultimately lost the congressional race, this tech gender gap had become my obsession, and I decided to pour all of my energy into solving it. After about a year of careful research, in the summer of 2012 several collaborators and I gathered 20 girls from all across New York City and for seven weeks taught them how to program. We called the project Girls Who Code. None of the girls had a background in computer science, but they all possessed a willingness and the bravery to try something new. During those seven weeks, I saw something magical unfold. I saw girls who began as strangers call one another sisters. I saw girls who thought coding was only for boys gain new role models who looked like them. And I saw girls who never thought they would be interested in the subject work together to build apps and Web sites addressing the issues that were closest to their hearts.

I did not know it at the time, but that first experimental Girls Who Code program was the seed of what today has become a national movement not only to teach girls computer science but also to foster a sense of sisterhood among them and introduce them to mentors in industry and academia. Five years later Girls Who Code’s Summer Immersion and year-round Clubs programs have taught about 40,000 girls ages 13 to 17 all across the U.S.—that is four times the number of girls who graduated with a degree in computer science in 2016. We have engaged thousands of volunteers and instructors in every state in the country, and this year we are launching a book series for girls to learn to code. We believe that bringing more women into the innovation economy of today and tomorrow is a critical step toward increased economic growth and opportunity.



The gender gap in computing does not start when a woman lands her first job or even when she goes off to college—it starts in middle school.



Reshma Saujani is founder and CEO of Girls Who Code. She is author of two books, *Girls Who Code: Learn to Code and Change the World* and *Women Who Don't Wait In Line: Break the Mold, Lead the Way*.

The key to our success has been knowing where the gender gap in computing begins. It does not start when a woman lands her first job or even when she goes off to college—it starts in middle school. Poor media portrayals and a lack of role models are largely to blame. In 1984 37 percent of computer science majors were women. Today that number is just 18 percent. It is no coincidence that in the 1980s personal computers were marketed heavily to boys—something that vastly changed public perceptions of what a computer scientist did and looked like. What began as an industry filled with women morphed into one where coders were nerdy guys working in a basement. Girls got the message and opted out in droves.

Despite our remarkable successes over the past

JESSICA SCRANTON



five years, the tech gender gap is still poised to grow. Last year we released a research report with the business and technology consultation company Accenture entitled *Cracking the Gender Code*, a study that looked at the shifting factors influencing girls' pursuit of computer science at every stage of their education. The report found that women's share of the U.S. computing workforce could decline from 24 to 22 percent if more is not done to tackle the gender gap. To date, most of the private-sector funding for early computer science education has gone toward providing universal access to computers and other educational tools rather than focusing specifically on young women. If we want to reduce and close the gender gap, we need to target girls and design interventions specifically for them.

Meanwhile the demand for computing skills continues to far outstrip supply, plaguing U.S. employers with a talent shortage. In 2015 there were more than 500,000 open computing jobs to be filled in the U.S. but fewer than 40,000 new computer science graduates to fill them. The demand for information technology jobs is likely to grow in the near future, proba-

bly at rates faster than most other occupations, which mainly now offer lower average salaries nationwide. The untapped potential of women to fill the IT jobs of today and tomorrow has vast implications for U.S. competitiveness.

PARTICIPANTS
in a Girls Who Code Summer Immersion program learn and practice the basics of computer science.

The current landscape may look bleak, but this issue is solvable. To reverse the declining trend, we need to invest in initiatives that are specifically tailored to sparking and sustaining girls' interest in the field from middle school onward through high school and into college. We cannot continue to take our eyes off gender. Today's middle school girls have the potential to fill 1.6 million extra computing positions by 2025—twice the potential of high school and college girls combined. Reaching that potential requires not only teaching girls to code but also teaching their instructors and their parents to portray programming as a cool, fun way for them to reach aspirations—not just a pursuit for boys. Access to a computer science education is a viable path to the American dream we all strive for and to the economic security and prosperity we wish for all our daughters. It is the same wish my father had for me. ■

MORE TO EXPLORE

The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution.

World Economic Forum, January 2016. www3.weforum.org/docs/WEF_Future_of_Jobs.pdf

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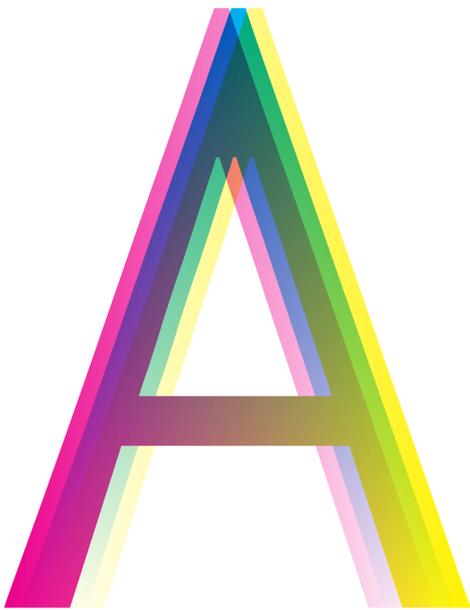
Ada and the First Computer. Eugene Eric Kim and Betty Alexandra Toole; May 1999.

scientificamerican.com/magazine/sa

THE BLOGGER AND THE TROLLS

Turning online harassment
into a force for good

BY EMILY TEMPLE-WOOD



AS A YOUNG GIRL, I WAS lucky to never explicitly hear that science was not for girls. Instead I was encouraged to build soccer-playing robots, to set things on fire, and to spend hours gazing through microscopes and telescopes. And yet I was still scared away from science as a career by the constant, subtle insistence from all around me that my purpose was not to be a scientist but rather a wife and mother—as if these things were incompatible. The implication was clear: no matter how many degrees I might earn, I was destined to give up.



WIKIPEDIA'S foremost biographer of women scientists and their cyber advocate, Emily Temple-Wood.

But I was not the kind of girl to shy away from being the only one in a group. In fact, I sought it out. Back then, all it took to convince me to do something was to tell me girls could not or should not do it. The problem with this attitude is that proving others wrong gets exhausting, in part because there are so many things girls are not supposed to do.

In middle school, I started editing Wikipedia articles and became one of the very few women regularly contributing—recent research from the Wikimedia Foundation shows that only 10 to 20 percent of the Web site's contributors are women. In high school, I excelled in speech and debate events, sticking my neck out in the mostly male-dominated competitions every weekend. Coached to pitch my natural voice down and to wear pants to be taken seriously, I curled

my hair, put on a strand of pearls and wore a skirt. Monday mornings, as one of only three young women in a physics class of 25 students, I tried my best to ignore the casual sexism of my classmates and instructors.

I continued to face casual sexism in college, and I encounter it even now as a medical student. There are still things girls are “not supposed to do.” Luckily, many of us are finding ways to ignore that expectation. Like any female trying to fight the status quo, for most of my life I felt that I had to be exceptional to pursue science. And why not? For many, if not most, children, boys and girls alike, the only women scientists they encounter will be the phenomenons, the exceptions. Yet this focus on a small number of extraordinarily successful female figures, rather than those who merely made significant contributions to science, can perversely reinforce the stereotypical belief that there is no precedent for ordinary women in science.

Five years ago I participated in Ada Lovelace Day, a celebration of women in science across the Internet. Writing about women scientists for this project with dozens of enthusiastic researchers, we discovered that more articles were needed than any one person could write in a year, let alone during the celebration. That realization led me to start a new “WikiProject” dedicated to creating and curating more biographies of women scientists. Now 95 people strong (and counting!), we work to write about the ordinary and extraordinary women who have shaped science from its inception.

An example of exceptionalism is, of course, Marie Curie (1867–1934), the physicist and chemist who performed pioneering research on radioactivity, a term she coined. Curie is often the first woman in science young girls learn about, often during Women’s History Month. Curie was an exceptional *person*, not just an exceptional woman. She remains, more than a century later, one of only two people to win two Nobel Prizes in different disciplines. And with the ever deepening specializations of scientists and physicians, she will likely remain forever unmatched. Yet Curie was not the first or only woman to become a scientist, nor was she the only woman to discover an element, to establish a new discipline of science or to thoroughly surpass her husband. Sixteen other women, including her daughter, Irène Joliot-Curie, have earned a Nobel Prize in one of the scientific disciplines: three in chemistry, one in physics, and 12 in physiology or medicine.

Most of these women, despite their achievements, are relatively unknown. Collectively, they barely scratch the surface of women’s contributions to science history. Their stories—like so many others—have hardly been told. When we began working on our WikiProject in the fall of 2012, I naively estimated there to be a couple of thousand women missing from our online corpus. To my delight, I could not

have been more wrong. After adding 4,900 scientists, many of whom could be found only in obscure and often offline academic sources, we find that there is still no end in sight.

Leaving aside the many troubling cases of extraordinary women researchers who were unjustly denied a Nobel, women have been an ordinary—rather than solely exceptional—part of science ever since its embryonic beginnings in ancient Egypt and Babylon. Women perfumers in the Cradle of Civilization were the first known chemists, and female doctors were recorded as early as the 27th century B.C., when a woman named Merit Ptah served as “chief physician.” By writing these and other women back into online accounts of science history, we hope to combat systemic biases that lead to the underrepresentation of women scientists on Wikipedia, in public discourse and in science itself.

Sadly, not everyone is supportive of this effort. I was practically bottle-fed online, so I should not have been surprised when misogynist Internet trolls slithered out of their hiding places to bash the project and personally attack me. One of the most common things I hear from them is that despite my hundreds of hours of research and writing, I am mistaken in thinking that women have ever accomplished anything important in the sciences.

These claims, of course, are patently false, and they are all too often accompanied by vile threats of rape, murder and violence against my family and me. Although I doubt any of these threats will ever come to fruition, they are still upsetting. To take back control, I made a promise to myself—and to the trolls: every time they harass me, I sit down with a hot cup of tea and a sleepy cat, and I write, adding more threads to Wikipedia’s burgeoning tapestry of women in science. These men (and yes, all of them are men, as best I can tell) hate nothing more than a woman who is successful and accomplished, and the women I write about are nothing if not successful and accomplished. Lucky for Wikipedia, there is a practically bottomless supply of abuse to draw on. And luckier for future generations, more and more people are participating in this project, each driven by their own profound sense of purpose.

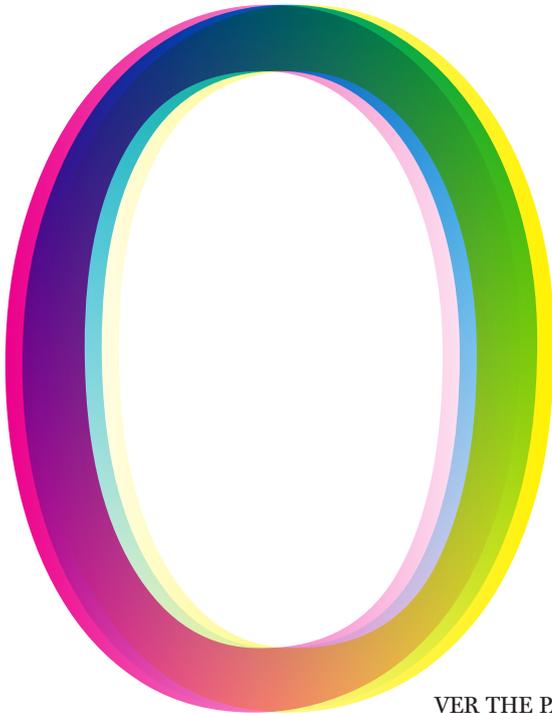
Even more than taking sweet, productive revenge on anonymous Internet trolls, we get the enormous privilege of keeping amazing women alive in our collective cultural memory. None of us controls who tells our stories, but we do get to choose the stories we tell. I choose to tell the stories of almost forgotten women, those who toiled tirelessly only for credit to be given to the men with whom they worked, those who died penniless and relegated to specialist encyclopedias, even those who were recognized briefly in their time but received only a small fraction of the credit they deserved. By bringing the legacies of women scientists to light, we can inspire the next generation. They will not be forgotten. ■

Emily Temple-Wood is a medical student at Midwestern University. In 2016 she was named a “Wikipedian of the Year.”

WOMEN'S WORK

As more women contribute to the economy, life gets better for everyone. Why are the barriers to opportunity so hard to change?

BY ANA L. REVENGA AND ANA MARIA MUNOZ BOUDET



OVER THE PAST 50 YEARS WOMEN and girls in developing countries have made enormous progress. Plenty of data illuminates this trend. Take life expectancy at birth: it went from 54 years in 1960 to 72 years in 2008. During the same period, we experienced the world's fastest ever decline in fertility. These changes reflect gains for women on many fronts, including education, employment, access to reproductive health and decision-making power, and it all happened much faster than it did in today's rich countries. It took India 44 years and Iran just 10 to reduce the number of children born to a woman from six to three; in the U.S., it took 123 years. Two thirds of all countries have reached

EDWIN REKSERG Getty Images (market in Swaziland)

CLOSING THE GENDER GAP
in employment would raise
productivity by 12 percent in
sub-Saharan Africa.



gender parity in primary education enrollment, and in more than a third more girls than boys are in school. In a striking reversal of historical patterns, women now represent the majority of university graduates. And more than half a billion women joined the labor market in the past three decades, which means that today four in 10 workers globally are women.

Yet amid all this progress, the remaining gaps are stubbornly resistant to closure. Although women on the whole live longer than men, in parts of the world such as sub-Saharan Africa they are as likely to die in childbirth as northern European women were in the 19th century before the introduction of antibiotics. Women still hold fewer positions of power in politics and business. And although many women work for pay, they do so under circumstances that weigh their talent, abilities and education differently from those of men.

These inequities are outrageous, and addressing them is both a rights issue and a fundamental objective of development. Just as we think development translates into less poverty and improved access to services for everyone, we also see it as a process of expanding freedoms. It promotes the ability to seize opportunities and decide on a life path. For us, pursuing gender equality—especially in women’s access to income-generation opportunities—is smart policy that itself leads to better development, not just the other way around.

Fully closing the well-being gap between the sexes requires specific, timely and intentional action. There are a few primary ways of doing this. First, remove the barriers that prevent women from having the same access as men to economic opportunities; this can generate higher productivity, and hence higher incomes, for all people. Second, increase women’s education, health and overall agency, which results in better outcomes for both mothers and their children. Third, put more women in positions of power. Giving women a representative voice shifts policies and spending toward issues such as sanitation, schooling and health. If only implementing these changes were as easy as identifying them.

IN BRIEF

Improving women’s

access to economic opportunity, education and reproductive freedom leads to better well-being for all.

Despite significant global progress in closing gender gaps, especially in developing countries, the remaining disparities between women and men are resistant to change.

Policies and programs that address entrenched social norms are the most promising solutions and must be intensified and expanded.

A PERSISTENT GAP

UNEQUAL ACCESS to economic opportunity is one of the major hurdles preventing progress. This is a problem in all countries, rich and poor, and in all industries, from farming to entrepreneurship.

The first roadblock is simply a barrier to entry: women must be able to access the economic space to participate in it. Although the female labor force has grown considerably in most parts of the world, a substantial participation gap is visible everywhere between men and women—53 percentage points in the Middle East and North Africa. Even if women can manage to break through that barrier, they are probably not competing on a level playing field. Female farmers have a more difficult time obtaining fertilizers, machinery and improved seed varieties, so their yields



HEAVILY “FEMINIZED” SECTORS, such as food production and teaching, tend to have lower wages. In all sectors, men still make more than women who hold the same position, even after factoring in education and age.

are often lower. Likewise, female entrepreneurs often have restricted access to capital and credit. Sometimes that is because they are less likely to own land or other assets required as collateral; other times it is because application procedures require a male co-signer or because banks assign female applicants a higher risk rating than male ones. This means that women-owned businesses are often less profitable, creating a chicken-and-egg cycle that is difficult to break. When these issues are corrected, overall productivity dramatically increases. A recent study showed that closing the gender gap in entrepreneurship would raise productivity and incomes by 12 percent in sub-Saharan Africa and 38 percent in the Middle East and North Africa.

Even in places such as the U.S. and Canada, where the labor-participation gap between sexes may fall below 15 percentage points, other factors hinder equality. Men and women tend to concentrate in different eco-

economic sectors, and it is easy to observe that women are more likely to work in education and social services, whereas men are more likely to work in construction and transport. But what is less noticeable is that women often occupy the lower-paid roles in whatever sector they are in. For instance, women are often teachers, nurses and clerical workers instead of principals, doctors and supervisors. Even as entrepreneurs, they tend to concentrate in traditionally female sectors such as food or clothing production.

Although we could discuss the preferences women (and men) might have for certain sectors, these patterns are not random. The problem is that those “preferences” reflect the influence of ideas and norms about “women’s work” and “men’s work” as well as other gendered attributes, such as the notion that women are better caregivers, whereas men are better suited for heavy physical work. The critical point is that heavily “feminized” sectors tend to have, on average, lower wages. And, of course, the gender difference in earnings is well known: Globally, a woman earns about 81 cents for each dollar a male worker earns. In Jordan and Côte D’Ivoire, the difference between incomes is more than 80 percent. Rich countries are not exempt: New Zealand has a low of about 5 percent; it is 36 percent in South Korea. But this difference reflects the different economic positions women hold. Even when you factor in characteristics such as education, sector and age that will make a female and male worker otherwise equal, the income gap persists. Female teachers in rural Pakistan, for instance, earn about 30 percent less than male teach-



Ana L. Revenga is deputy chief economist at the World Bank Group. She has led the institution’s work on poverty and equity issues in her 24-year career.



Ana Maria Munoz Boudet is a senior social scientist at the Poverty and Equity Global Practice at the World Bank Group. She is part of the bank’s Mind, Behavior, and Development Unit.

ers. Understanding—and addressing—the entrenched social norms behind these persistent gaps is key to closing them.

STUBBORN SOCIAL NORMS

ONE OF THE MAJOR CAUSES of lower earnings and productivity stems from constraints on women’s time. Women devote far more of their days to care and household work than men, which in turn means that women have less time for paid work. Deep-rooted social norms drive the differences in “domestic” roles. What is most striking is that these norms, and hence patterns of time use, do not change even as women take up a larger share of market work. In Ghana, a wife still does more than 80 percent of the housework even when she brings home all the income. This imbalance is largely true elsewhere as well, including the U.S. Even in the most progressive places, this pattern reflects assumptions about the division of roles, identifying them as natural and biological instead of cultural. As such, we all live as though this is just the way things are. You can see the effects everywhere in the workings of societies, households and markets. Look at school schedules, which are not consistent with a full-time employment day, or laws that allow mothers—but not fathers—to use sick days to care for an ill child. Breaking these patterns requires upending default expectations.

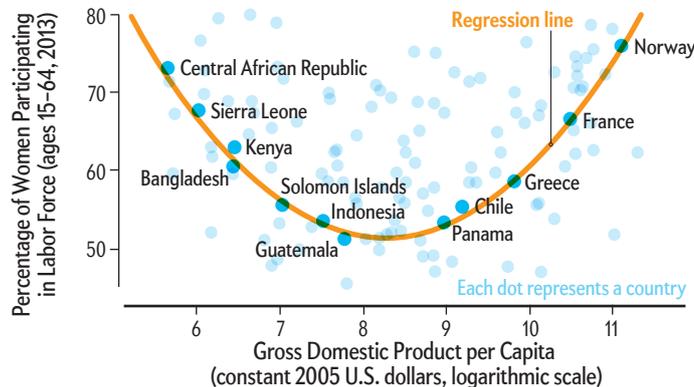
Unfortunately, policies used to address the time-constraint issue primarily work around these norms instead of confronting them head on. While the results are promising, it’s not a complete solution. The most popular example of this is providing increased access to child care services and improving parental leave policies. As expected, the expansion of access to early child care and preschool services consistently leads to higher labor-market participation of women across all countries. Expanding child care accessibility (location, times of operation), affordability (direct and related costs) and capacity (removing waiting lists, including different ages of children) has a positive impact on the mother’s labor engagement.

There is ample evidence that this policy change often alleviates constraints on working mothers’ time. In the early 1990s Argentina embarked on a program to expand early childhood education. It resulted in the creation of 175,000 preschools over seven years. Researchers observed labor patterns as the program expanded and found a positive impact of between 7 and 14 percentage points in mothers’ employment. Most notably, these positive effects hold even when the preschool is only part-time.

But policies such as allocating more time to maternity leave—and adding paternity or parental leave to include fathers—have not always been as successful. In Germany, the expansion of maternity-leave regulation and coverage led more women to ultimately return to work with their prebirth employer. But when neighboring Austria shifted its maternity leave duration in 1990 from one year to two years, it significantly reduced the

A Labor U-Turn

Female labor force participation tends to be high during the early stages of economic development, when countries are poor and households cannot afford for anyone not to work. A large part of the work is agricultural production. As countries transform from rural societies into industrial or urbanized ones and more income starts flowing into homes, the types of jobs change, and more women stop working. As countries mature into modern service economies, women return to work but in different economic spaces.



SOURCE: ANA MARIA MUNOZ BOUDET (data from World Development Indicators, World Bank)

percentage of women who returned to work at all.

Then there are the parental-leave programs in Scandinavian countries, which give fathers an incentive to share the load after the birth of a child. When they were first introduced, they were rarely used by men. But when such a policy in Sweden specifically gave fathers dedicated, nontransferable leave, it delivered positive results in terms of getting fathers to spend more time with their children. Studies have shown that these men remain very involved in parenting over time but slowly transition out of other domestic tasks as the leave effect ends.

Similarly, differences in human capital often affect women's career trajectories. The root of the problem is not a difference in ability or capacity between the sexes—it is discrepancies in how we invest in and value women as workers. In developing countries, these differences appear as access to and completion of education; in more developed countries, where educational attainment is higher and both men and women attend university in large numbers, gender differences show up in fields of study. In the U.S., for example, women represent less than 35 percent of the degrees in the science and technical fields even though they account for almost 60 percent of college graduates.

When it comes to bridging human capital between men and women, governments must make investments beyond traditional education to include training, apprenticeships and other labor policies. Young job seekers are an important target of these policies. One notable example is the series of Jóvenes (youth) programs implemented across Latin America in the early 2000s, which encompassed a combination of training, internships and incentives to employers with a goal of breaking biases in hiring young workers. Across the board, these programs increased the probability of young women becoming employed and boosted their earnings.

But efforts to translate the lessons from the Jóvenes programs to other settings have had uneven results. An evaluation of a similar vocational-training program in Malawi found that family obligations limited female participation. The Jordan New Opportunities for Women pilot involved more than 1,000 young women from community colleges. Demand for the program was extremely high: many of these women successfully completed the vocational training, and half of those graduates found jobs thanks to wage-subsidy vouchers provided for employers. But the effects were short-lived, and no changes were found in employment or earnings. Here again, it appears that social norms and employers' views about women heavily impeded successful replication of the initiative.

The third driver of gender inequality in economic opportunities is what we would typically call discrimination: the differential treatment of women by markets and institutions. When few women are employed in a certain sector, employers may hold biased beliefs about their qualifications. They may be reluctant to hire women because they associate extra costs, such as



CONSTRAINTS on women's time are pervasive in both rich and poor countries.

maternity leave, with female employees, or they may assume that women are not the primary breadwinners and therefore lack motivation. A number of studies that compare the reactions of employers with otherwise identical female and male CVs found substantial evidence of gender discrimination when it comes to recruitment and hiring. Moreover, access to jobs often involves gendered networks: when women are poorly represented in an occupation, they are less likely to become aware of opportunities and may be unable to find mentors. In many countries, gender-specific job advertisements and gender-biased selection criteria and recruitment are still common. In an astonishing 174 of the 189 countries in the Women, Business and the Law database, employers are not prohibited from asking job applicants about family status and family planning.

In Ghana, a wife does more than 80 percent of the housework even when she brings home all the income. Such imbalances also exist in the U.S.

Government institutions can also treat men and women differently, often in ways that play against women's interests. For example, in 66 percent of countries, women cannot do the same jobs as men. Many former Soviet countries are particularly restrictive. In Russia, there are nearly 460 occupations currently forbidden to women, including steelworker, firefighter, oil-well worker and bus operator. Others countries require women to get male permission to accept jobs, open bank ac-

counts or operate businesses. In Chile, husbands have the sole right to administer marital property, regardless of whose income or savings was used to purchase the property. In Pakistan, a married woman cannot register a business in the same way as a married man. In Mongolia, many women cannot work at night. In Yemen, a husband can object to a wife's employment.

These three sets of differences between men and women—in responsibilities for care and housework, in human capital investments, and in treatment by markets and institutions—not only get in the way of equitable economic opportunities but often do so in ways that reinforce one another. Devoting much more time to care and housework may encourage women to self-select occupations that offer greater flexibility in hours but trap them into lower pay. This is especially true if formal employment options come with restrictions on part-time work, as is the case in many developing countries. Preemptively knowing it will be hard to get a job—and fit in—in a male-dominated field such as engineering or construction may discourage girls and young women from acquiring the education and skills necessary to pursue those opportunities. And repeated experiences of discrimination in job applications and hiring may push women toward informal self-employment or discourage participation in the labor market altogether, which starts the cycle of inequality all over again.

FINE-TUNING THE SOLUTIONS

WHY, IF WE HAVE been able to clearly identify the roots of the gender gaps in economic empowerment, does change remain so elusive? For starters, the multiplicity of factors requires many actions coordinated toward the same goal. And given that the nature, structure and functioning of markets, institutions and norms varies widely across countries, a one-size-fits-all policy approach is impossible. As we have shown, policies that were successful in one context may face significant resistance in another.

Still, a few general principles have proved critical for successful policies. To be effective, policies and interventions need to target the multiple underlying factors that drive gender differences in access to economic opportunities. That is, they need to directly address the constraints on women's time that arise from gendered social norms about care and housework, not circumnavigate them. To increase productivity, they must fill the gaps in information, skills and access to professional networks that constrain the opportunities of female wage workers, farmers and entrepreneurs. And they need to help build a more level playing field in markets and institutions by targeting discriminatory preferences.

One such promising example of a dynamic intervention hits many of those targets. The Empowerment and Livelihood for Adolescents program (ELA) implemented in Uganda by the nongovernmental organization Building Resources Across Communities provided young women aged 14 through 20 with life skills and

vocational training at “girls’ clubs” where a mentor was present to lead activities. The clubs also served as a safe space in which adolescent girls could meet, socialize and recreate. A quarter of the girls in the 100 communities selected for the evaluation participated in the program, and the results were impressive. Girls in ELA communities were 72 percent more likely to be engaged in an income-generating activity four years later. But most important, the program shifted the girls’ attitudes and aspirations. For example, the participants were more likely to believe that women should earn money for their families and less likely to be worried about finding a good job in adulthood. Strikingly, those shifts helped teen pregnancy rates fall by 34 percent, and early entry into marriage or cohabitation dropped by 62 percent.

Policy makers, too, must learn from their own successes and failures and those of others. To achieve that, they must be able to clearly articulate both what goes into the policy and its expected impact. These initiatives also need to be piloted and properly evaluated before taken to scale. Too many interventions designed to support gender equality rely only on good intentions and intuitions. While some might deliver in terms of outputs—say, the number of women who received training from a vocational program—many fail to deliver the expected final outcome, which in this case means getting more women to enter (and stay in) the labor market.

Policies and programs that show the greatest potential should be expanded and intensified. They must not be stopped even once the desired objective seems to be achieved—long-term follow-through is especially critical when tracking social changes as well as logistical ones. Progress requires constant, concerted and coordinated action to make markets, institutions and societies as a whole work more fairly for women, and changing the long-standing norms about women's and men's roles both at home and at work is a tall order. Resources for gender-specific interventions compete with other urgent development priorities, such as food security and poverty reduction. And goals like those can have no specific effects on closing gender gaps. That is why it is essential to rely on tested and proven tactics instead of leaning too heavily on advocacy and good intentions. Greater gender equality is achievable with a combination of political will and evidence-based policies. Women and men of the future all stand to benefit from a more equitable society. ■

UNEQUAL SEATING

Only around **20** women

hold the office of head of state or government around the world.

A mere **23%**

of parliamentary seats are occupied by women globally.

Rwanda has the highest female representation:

61%

of the 80 seats in the country's lower house are held by women.

MORE TO EXPLORE

- World Development Report 2012: Gender Equality and Development.** World Bank, 2012.
- Aggregate Effects of Gender Gaps in the Labor Market: A Quantitative Estimate.** David Cuberes and Marc Teignier in *Journal of Human Capital*, Vol. 10, No. 1, pages 1–32; Spring 2016.
- Breaking the STEM Ceiling for Girls.** Ana Maria Munoz-Boudet and Ana Revenga in *Future Development* blog, Brookings Institution. Published online March 7, 2017.

FROM OUR ARCHIVES

- Six Billion in Africa.** Robert Engelman; February 2016.

scientificamerican.com/magazine/sa

MIND THE GAP

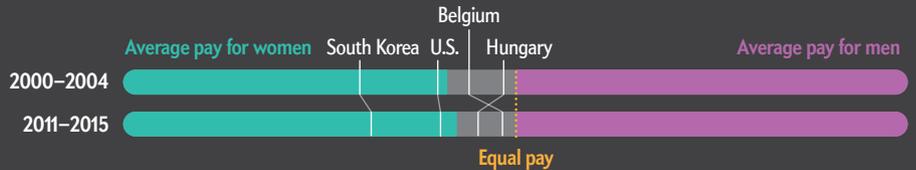
Gender inequality remains a global phenomenon

Data from the past few decades show that despite progress toward gender equality, many challenges persist. Women are still disadvantaged compared with men where access to economic and social opportunities is concerned. Some of these so-called gender gaps, such as the dearth of women in government, stem from societal attitudes about gender and leadership. Others arise from factors that by definition disproportionately affect women, such as restrictions on reproductive health care.

—Amanda Montañez

PAY

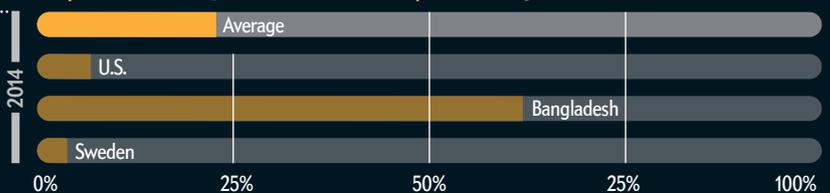
Across the globe, female employees earn less on average than their male counterparts. Despite improvement over the past decade, none of the 31 countries represented here has eliminated the gender wage gap.



EDUCATION

In some parts of the world, including the U.S., women make up more than 50 percent of college graduates. But globally, nearly a quarter of the population thinks that university education is more important for boys than girls. This chart includes data from 85 countries.

People who believe higher education is more important for boys



MARRIAGE AGE

Women tend to get married at younger ages than men. Based on data from 104 countries and territories, this chart represents the average age of those who marry before age 50.

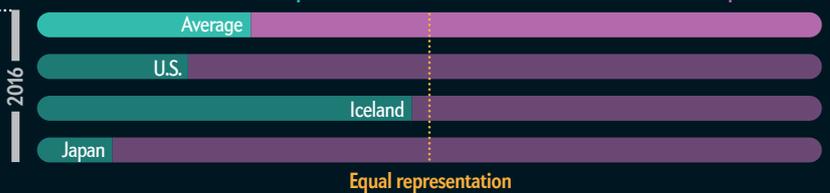
Average age at marriage for women vs men



SEATS IN GOVERNMENT

Although they make up roughly 50 percent of the population, women are vastly under-represented in government. Drawing data from 44 countries, this chart shows the average share of female seats in national parliaments.

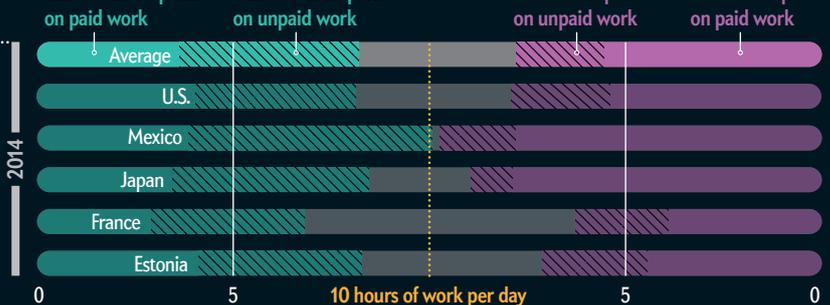
Share of female seats in national parliament vs male seats



UNPAID WORK

Women spend more time working every day than men do, but a comparatively high percentage of that labor is unpaid. Tasks such as child care and housework contribute to the imbalance represented in this chart, which draws on data from 29 countries.

Time spent on paid vs unpaid work

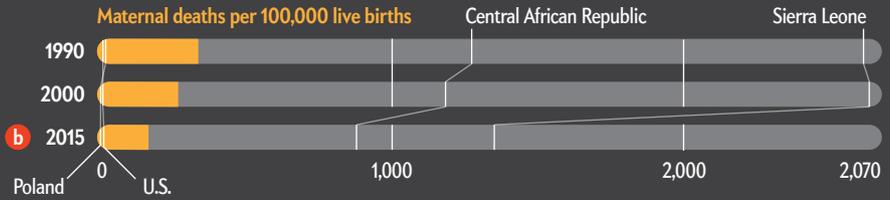


GENDER GAPS

RECENT PROGRESS

MATERNAL MORTALITY

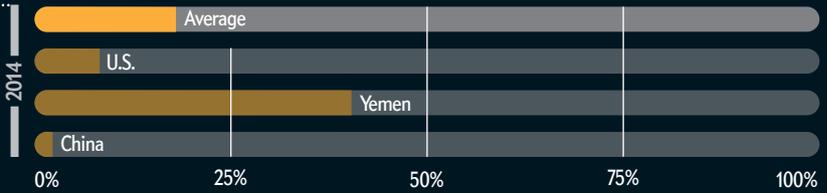
Data from 181 countries and territories show that, on the whole, the rate at which women die of causes related to pregnancy or childbirth has been steadily declining over recent decades. That rate remains high in many developing countries, however.



CONTRACEPTION

Data from 120 countries indicate that, globally, about 18 percent of married women between the ages of 15 and 49 have an unmet need for contraception.

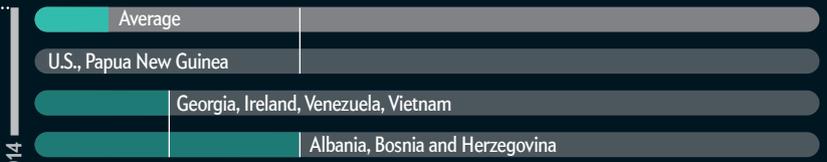
Married women aged 15–49 who have an unmet need for contraception



PAID PARENTAL LEAVE

Women shoulder most of the responsibility of child care, particularly during infancy. Most national governments mandate some amount of paid time off work for new parents, according to data from 160 countries. In those outlying countries that fall short in this category—including the U.S.—mothers disproportionately pay the price.

Length of mandated maternity leave



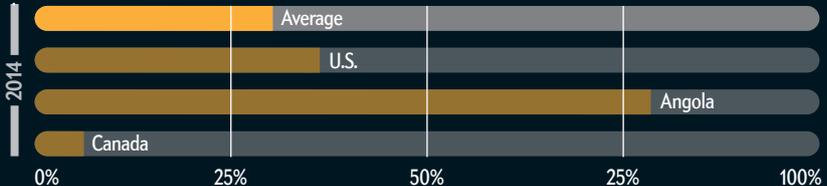
Length of mandated parental leave



DOMESTIC VIOLENCE

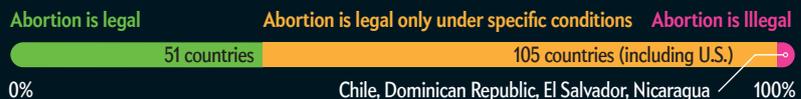
Data from 103 countries reveal that a high percentage of women suffer physical or sexual violence from an intimate partner at some point in their lives.

Percentage of women who experience domestic violence



ACCESS TO ABORTION

Abortion remains illegal or restricted in most of the 160 countries represented here. Constraints on abortion access range from gestational limits (such as banning abortion after 20 weeks) to laws that allow abortion only in cases of rape or incest or when the life of the mother is endangered.



ISSUES PRIMARILY AFFECTING WOMEN

a The small New Zealand territory of Tokelau is one of the few places in the world where brides are slightly older on average than grooms. The mean age at marriage there is around 28 for women and 27 for men.

b The maternal mortality rate in the U.S. is well below the global average. It is higher than that of other wealthy countries, however, and has increased in recent years, from 12 deaths per 100,000 live births in 2000 to 14 per 100,000 in 2015.

c Clinicians generally recommend that mothers who have given birth exclusively breastfed their infants for the first six months of life, making that interval a logical minimum for paid maternity leave.

RETURN OF THE MISSING DAUGHTERS

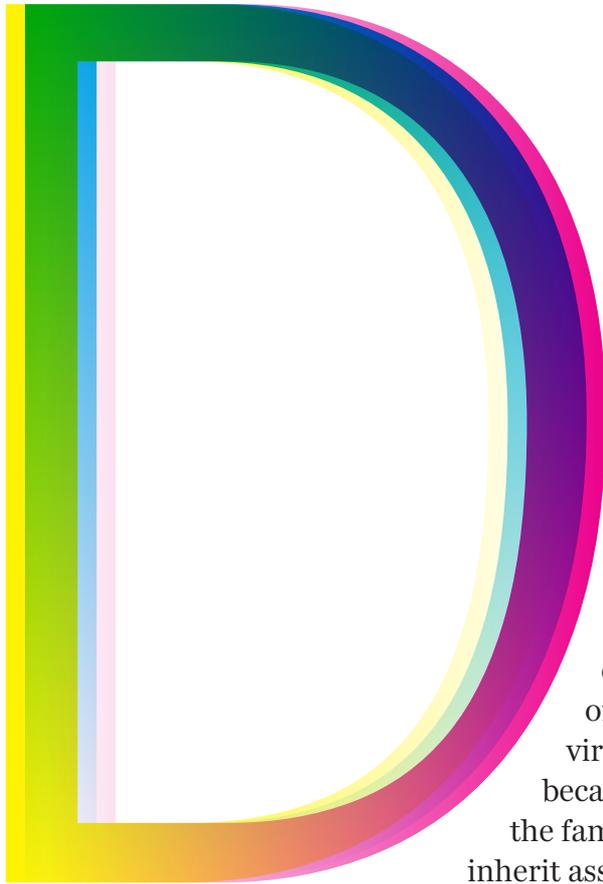
Traditions that favor sons in Asia—
resulting in millions of dead or neglected
girls—have started to change

BY MONICA DAS GUPTA

Illustration by María Corte







“DAUGHTERS ARE USELESS AND UNWORTHY!” shouted an elderly woman in a village near Busan in South Korea in 1996. Other old women sitting with her, as we talked about families, nodded their agreement. Why, I asked? It was not because daughters were lazy, she said. “No, women did a lot of hard labor in the fields, and their marriage costs virtually nothing. People don’t want daughters, because they are not helpful to the family—they leave the family when they marry. It is *sons* who stay home, inherit assets and keep the rituals of ancestor worship.”

IN BRIEF

Until very recently, many cultures in Asia and elsewhere have valued boys more than girls, and female children were often killed or neglected by their families.

Generations of missing women have been harmed, and their absence has hurt societies, altering marriage patterns and migration in and out of regions and countries.

Now more gender equality is starting to take hold, and as cultures grant more economic value to women, birth ratios no longer favor sons so heavily.

In China, I heard similar stories. A man said that when his daughter was born, “my wife was so upset that she did not want to care for the child, and I had to persuade her to nurse it.”

These attitudes have had life-and-death effects. The natural human male-female birth ratio is only about 5 to 6 percent more boys than girls. But in China in 2000, there were 20 percent more boys born. This kind of skewed sex ratio has been found across much of East Asia, South Asia, the southern Caucasus and parts of the Balkans. Female babies are aborted in these areas, killed at birth or die through neglect. Why? As the woman from Busan said, it is brutal economics. These cultures have historically excluded adult daughters from helping in their parents’ households or inheriting property, which diminishes their value to their birth family.

But recently the demographic bias against females has begun to shift. South Korea has shown a rebalancing of child sex ratios since the mid-1990s, with proportions of boys to girls dropping from high levels to biologically normal ones. There is even a shift toward a preference for daughters in South Korea today. In India, the 2011 census shows a sharp drop in

sex ratios in children in the northwestern part of the country, where they had been very high. In China, the climb in such sex ratios has leveled off.

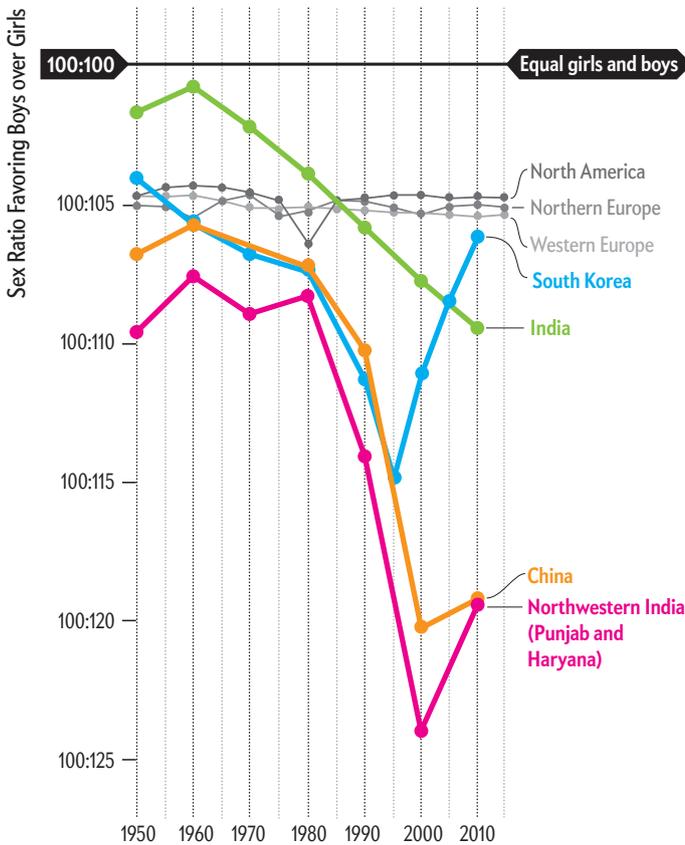
These shifts coincide with rapid urbanization and social changes that have helped make daughters more valuable to their parents. Daughters no longer vanish from their birth families, and in some cases, they bring in additional men from outside. Twenty years after my original fieldwork in Busan, one woman in South Korea told me, “My mother suffered a lot of abuse when she was young because she had three daughters and no sons. Now that we are grown, she is very happy because we all remain close to her. She says that her sons-in-law treat her better than sons.”

SHOVING WOMEN OUT

FOR CENTURIES the social organization of rural society in China, South Korea and northwestern India pushed daughters away from their parents’ households. When women married, they were absorbed into their husband’s family. New labor in their birth family was provided by daughters-in-law marrying in, further emphasizing the value of sons. A similar social structure appears in other regions with strong

Different Places and Losses

South Korea, China and northwestern India lost many girls during the 20th century—victims of infanticide or neglect in patriarchal cultures. Census data and population surveys show drops in the numbers of girl babies and young children, compared with those of boys. The effect was not seen in Europe and North America. Recently cultural values have changed, and girls have rebounded.



son preference, including northern Vietnam and the southern Caucasus countries.

To cement this daughter transfer, when a woman joins her husband's family, her "slot" in her birth family is eliminated. A new slot is created for incoming brides. If women do return—a rare occurrence—they and their parents have to struggle hard to make the unusual situation work. Other members of the family and the village resist because of the potential reduction of their property rights. Once a woman from rural China has been married and her land entitlement reallocated among village residents, for example, her return can be met with a fair amount of antagonism.

The impact of these cultural norms can be seen in the contrast between elder living arrangements in

countries such as Taiwan and South Korea and those in countries such as the Philippines. The first two have rigidly patrilineal (male-oriented) kinship systems, whereas the third has a system of kinship that does not favor children of any one gender. In Taiwan and South Korea, a substantial proportion of parents live with married sons, but almost none live with married daughters, according to a forthcoming study I conducted with Doo-Sub Kim of Hanyang University in Seoul. In the Philippines, parents are equally likely to live with married children of either gender. It is not surprising that child sex ratios are normal in the Philippines but have been lopsided in Taiwan and South Korea.

The results of devaluation of females are not surprising, either. Unwanted girls have been removed through infanticide and neglect, producing male-skewed child sex ratios. Beginning in the 1980s, sonograms and other technologies for prenatal sex detection made it possible to act on sex bias even before birth. The new methods made it easier for parents to avoid having unwanted daughters—through abortion—and sex ratios at birth showed more imbalance.

Major disruptions such as famine and war heightened the pressure on parents to get rid of children they perceive to be superfluous. Beginning in 1937, Japanese troops swept through eastern China, and girls went "missing:" 17 percent more girls died than one would expect from typical mortality rates in this situation. Parents in war-torn regions felt that they had to make some harsh choices. A woman in the province of Zhejiang told me of her own experience in the 1930s: "When I was six years old, my mother said that I should be sold. I begged my father not to do this, that I would eat very little if only they would let me stay at home." The collapse of governmental institutions can have similar effects. In the southern Caucasus countries, for instance, birth ratios favoring boys shot up when the U.S.S.R. was dissolved.

A shift from large to small family size also increases the pressure on parents to select for sons. In large-family, high-fertility settings, parents can afford to have several daughters and still go on to have one or two sons. In small families with fewer births, there are only limited chances to have sons. The second girl born into such families in son-favoring cultures has a much higher chance of dying before birth or during early childhood.

WHEN BRIDES ARE IN SHORT SUPPLY

THE DEATHS of these female babies are a shocking result of gender inequality. The damaging effects ripple through society. Eventually they translate into a shortage of adult women. And after heightened periods of sex selection in earlier decades, a "marriage squeeze" now grips China, South Korea and northwestern India. China presents the starkest scenario. In 2010 the Chinese Academy of Social Sciences estimated that by 2020, one in five men in China will be unable to find a wife.



Monica Das Gupta is a research professor at the University of Maryland's sociology department and is a former senior demographer for the World Bank.

SOURCES: "MISSING GIRLS IN CHINA AND INDIA: TRENDS AND POLICY CHALLENGES," BY GUO ZHEN, MONICA DAS GUPTA AND LI SHUZHOU, IN *ASIAN POPULATION STUDIES*, VOL. 12, NO. 2, PUBLISHED ONLINE JUNE 6, 2016 (children in India, ages 0-6, and children in South Korea and China, ages 0-4); NATIONAL CENSUS DATA (China, India, South Korea); WORLD POPULATION PROSPECTS: THE 2017 REVISION, POPULATION DIVISION, DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS, UNITED NATIONS, 2017 (North America, Western Europe, Northern Europe)

The bride shortage affects poorer men most severely. In China, Shang-Jin Wei of Columbia University and his colleague report that poorer parents in areas with imbalanced sex ratios struggle to improve their sons' chances in the marriage market. The parents resort to desperate measures such as taking on dangerous work to earn more and build a nicer house, one that can attract this newly scarce and valuable commodity: a bride to marry into the family.

At the same time, the marriage squeeze can benefit women. In areas of China with fewer potential brides, a study by Maria Porter of Michigan State University found that women have greater bargaining power within their marriage, enabling them to provide greater support for their parents than before. Women from poor areas can marry men who offer higher living standards, either locally or by migrating to other parts of their country. Some migrate to other countries to marry better-off men. In China, South Korea and India, several studies show these long-distance suitors are typically socioeconomically disadvantaged compared with other men in their own locale. They are unable to attract a local wife but still can offer an improved standard of living to women from impoverished regions.

These migration marriages do come with risks for women, however. Some research suggests that women who come from different ethnic or linguistic groups face problems in assimilation, are viewed as outsiders, do not know the local language and customs, and have limited social networks in their new setting. Many such marriages are to men who live in rural areas, and rural life further isolates the brides.

Difficulties can go beyond social isolation and cultural misunderstandings. In a 2010 study of Vietnamese brides in Taiwan, done by researchers at Viet Nam National University, Ho Chi Minh City, most women said that they were happy because they were able to help their birth families financially. But some mentioned problems, such as being humiliated by their husband and in-laws for their poverty, suffering domestic violence or being made to work like a slave. In Taiwan, in fact, a 2006 study found that marriage migration was a risk factor in domestic violence. And in South Korea, Hanyang's Kim found a greater likelihood of divorce among such marriages.

Some researchers and policy makers have also suggested that the creation of a generation of enforced bachelors may raise levels of crime and violence, including violence against women. Crime levels climbed in areas with higher male-to-female ratios, according to a study in India led by Jean Drèze of the Delhi School of Economics, as well as another study, which was conducted in China by Lena Edlund of Columbia and her colleagues.

THE VALUE OF WOMEN

OVER THE PAST TWO DECADES the bias against girls has begun to diminish. My colleague Woojin Chung and I

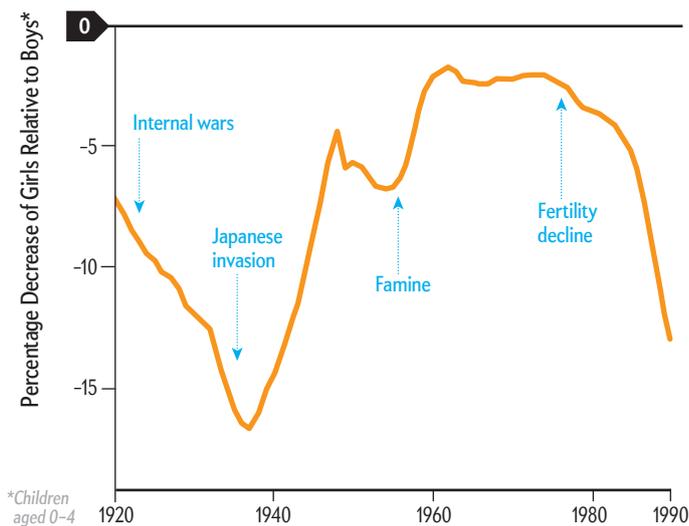
What turned the corner, enhancing girls' value? It is hard to tease out, but increasing urbanization and education of parents play a major role.

documented this phenomenon in a study of South Korean women's changing attitudes toward children's gender. When interviewed in 1991, 35 percent of women born between 1955 and 1964 said that they "must have a son." But by 2003, only 19 percent of women born in that same period held this view. Changes in attitude have swept across society. Even after accounting for differences in education levels and urban versus rural residence, the odds of women aged 15 to 49 stating they "must have a son" in 2003 were roughly one third of the 1991 level. Changes in social norms account for as much as 73 percent of this decline. Only 27 percent of the drop is caused solely by increases in individual levels of education and urbanization. When attitudes changed, child sex ratios followed, as shown in the box on the opposite page.

What turned the corner, enhancing girls' value? It is a hard answer to tease out, but the increasing

In Hard Times, Girls Suffer

In China, the numbers of girls have dropped, compared with what would be biologically normal, during difficult times. Families jettisoned less valued female children during internal wars in the 1920s, a Japanese invasion in the late 1930s, famine in the 1950s and pressure to have small families in the 1980s.



SOURCE: "GENDER BIAS IN CHINA, SOUTH KOREA AND INDIA 1920-1990: EFFECTS OF WAR, FAMINE AND FERTILITY DECLINE," BY MONICA DAS GUPTA AND LI SHUZHOU, IN DEVELOPMENT AND CHANGE, VOL. 30, NO. 3, JULY 1999

urbanization and education of parents play a major role. South Korea, for example, has urbanized at blistering speed, with the percentage of people living in and around cities doubling between 1966 and 1986, from 33 to 67 percent. By 1991, 75 percent of the population lived in urban areas. The effects of urban life on son preference are both social and economic. Living in a city reduces the centrality of sons' roles in their parents' lives. While villagers spend their days surrounded by clan members, urban residents live and work in the more impersonal settings of apartment blocks and office complexes. This shift relieves pressure to conform to traditional expectations of filial duty and to have sons to continue the lineage.

In urban areas, children who support their parents tend to do so less because of formal rules and more because they happen to live in the same city and have strong relationships with their parents. In this way, urbanization helps to bridge the gap between the value placed on daughters and sons. Female education and employment also enhance the potential support they can offer. And with growing access to pensions and social protection systems, people become less dependent on their children for financial support.

Government policies have also nudged male preference into decline by encouraging mainstream equality for women. India has used affirmative action to increase women's political participation, putting a female quota in place for candidates for local government positions. Social scientists have found that after the policy was created, gender stereotypes weakened in the population as a whole, and girls' aspirations for themselves rose.

Extensive media outreach has also been a staple feature of family-planning programs in India, China and South Korea. Posters and commercials encourage parents to have small families even if they do not include sons. These efforts promote the view that daughters are just as good as sons for family happiness.

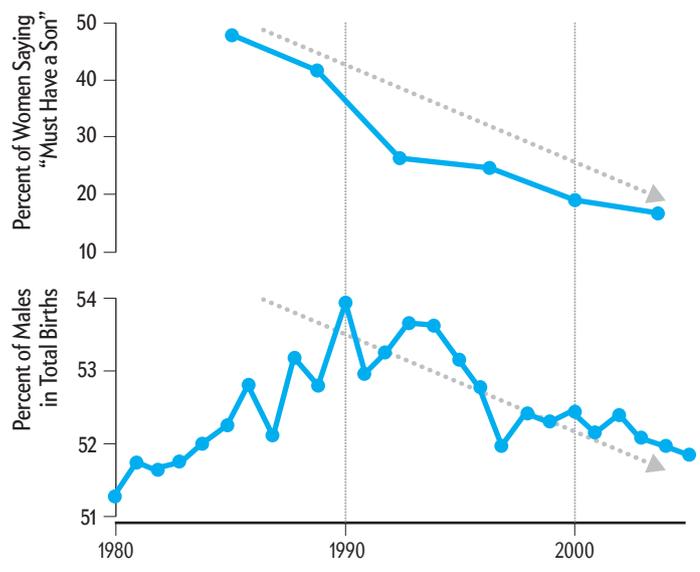
Female characters in popular Indian television soap operas now work outside the home and are active in public life. The values and roles illustrated in these programs challenge traditional views of a woman's place in society. Studies show that exposure to these messages is associated with reduced son preference.

There have also been direct attempts to change sex ratios by banning the use of technology for prenatal sex detection and selection. These bans have been put into place in several countries, but there has been little rigorous evaluation of the impact of these measures because of a lack of data. India's ban on sex selection appears to have had at most a modest effect. A vigorous effort in China to ban birth selection has shown little effect on the national sex ratio of babies.

Countries in Asia are still urbanizing rapidly, so I believe the preference for sons will continue to

Sex Ratios Follow Social Preference

In South Korea, the stated desire for sons instead of daughters dropped sharply by the early 1990s. The actual percentage of sons born began falling soon after that, showing the power of changing values.



decline. Policy makers can accelerate this process through legal and other measures enhancing gender equity. They can also expand media advocacy and portray women helping their own aging parents (not just their in-laws). Such steps help to change gender stereotypes and overcome parents' preference for sons. For women—and for society in general—such approaches may have better outcomes than outright attempts to ban the selection of sex at birth. ■

MORE TO EXPLORE

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FROM OUR ARCHIVES

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scientificamerican.com/magazine/sa

THE WOMAN WHO SAVED THE PLANET

By harnessing “female energy,” Christiana Figueres convinced humanity to take on climate change

BY JEN SCHWARTZ



One could argue that Christiana Figueres, a 61-year-old Costa Rican diplomat, warded off global catastrophe. As former chief of the United Nations Framework Convention of Climate Change, she orchestrated the 2015 Paris climate agreement, which, for the first time, got virtually all nations to take action on greenhouse gas emissions.

Figueres achieved unprecedented cooperation not by flexing her authority (the position carries very little) or fixating on the most powerful players but by inviting a massive number of diverse voices into a weblike conversation on solutions. Trained as an anthropologist, she bet that humans are motivated to work toward a common goal if given a structure of trust and hopefulness. So in the face of high stakes and daunting complexity, she created an even bigger mess, imbued it with optimism, then navigated through it. Now she is focused on carrying out the goals of the agreement as the head of Mission 2020, a plan to “bend the curve of emissions” over the next three years.

Although Figueres “never had a master plan” for her career trajectory, her résumé was seemingly built for leading at the intersection of science and policy: 14 years as a negotiator in the Costa Rican government; head of a climate-focused nonprofit; adviser to the private sector; bicultural, trilingual diplomat from an environmentally aware nation. Here Figueres shows what can happen when dynamic women lead the way. Edited excerpts follow.

Scientific American: In dealing with sweeping global issues, your leadership style involves ceding some control of the granular details. Do you think there’s a “feminine” quality to this approach?

Figueres: It’s dangerous to generalize and simplify: *males do this, females do that*. Having made that disclaimer, there’s certainly a female energy—which we all have, by the way—that’s much more flowing and organic, compared to a male energy, which we also all have, that is more directional and linear. We happen to call it “male” and “female,” but we could call it anything, like yin and yang. In different periods of my life, I did exercise many of my responsibilities with male energy in order to be at the table.

Looking back, I’ve always had a willingness to be vigilant to where the opportunity is. You don’t have to progress in a straight line; you can be creative. Perhaps it’s like a sailing strategy, tacking left and right, left and right. Or sometimes it’s stepping back one foot so you can then step three feet forward. I think women are more willing to continuously learn, regardless of age.

Male energy tends to put things into black and white and force you to choose between A and B rather than saying, “there’s A.A and then A.AB.” With regard to the Paris agreement, we had to be able to look at the shades of gray in between many realities, to see differences as complementary, not mutually exclusive. In particular, it was very important for me to change atti-

Jen Schwartz is senior editor for technology and mind for *Scientific American*.



tudes around the relationship between the global north and global south. We had to get to the point where there was full and deep recognition of historical responsibility but also at the same time a recognition of shared future responsibility.

As the architect of one of the most complex international agreements in history, how was your strategy different from previous efforts that failed?

The negotiating of the text itself is according to very strict U.N. procedures. But exactly how we were going to get there was the result of six years of conversation.

From my anthropology background, I drew a conviction that this had to be an inclusive process, not just federal governments. So we opened it up to the private sector, the spiritual community, the scientists. Humans tend to gravitate toward other conversations that are related to ours. There is sort of a self-organizing force that occurs, and better decisions are made when they are informed by as many different perspectives as possible. It's indicative of female energy to be on the lookout for which voices are not at the table and should be.

In the beginning, we tried to map it out: Who is doing what by when and with whom? I very quickly realized, "Thank heavens this is not map-able!" The participation was so broad, and the scenarios were changing so quickly that coordination was impossible. When you're dealing with something as decentralized and as universally felt as climate change, a logical flow of events is frankly not helpful. It diminishes the power of a potential solution. Instead we needed to get an agreement on the final place we all want to land—and that was provided by the science. The ultimate objective was an ambitious, fair structure that would bring everybody under one tent in a differentiated way. Then, we allowed for everybody to use the tools they have to apply the science to their particular country, sector or issue.

To all those who suggested, "This is too complex, we can't do it by 2015, let's begin a plan to delay by six months," I put my foot down and said, "We are not even considering it." You must allow for the process itself to be muddy because that is the space in which innovation occurs, ingenuity sprouts up and surprising alliances come forward. You want to be not only tolerant but even encouraging of the messiness—but with a hard deadline and a clear destination.

Opening up the conversation was one of the most difficult things we did but one of the most important. The result is a framework for which there is broad and deep buy-in. That's what makes it strong.

The dialogue around climate change can seem dire. Why is a hopeful attitude so important?

When you're inside the negotiations, that's one world, and then there's the outside world. I created a surround sound effect so that no matter where governments turned to in the outside world, they would feel encouraged that everyone was moving in the same di-

rection. I wanted them to hear a chorus of yes, yes, yes. Yes, we can go forward with ambition, yes, this makes economic sense, yes, the technologies are there, yes, the science is there, yes, the morality is there.

Doesn't President Donald Trump's withdrawal from the agreement make the outlook gloomier?

The federal governments of the world did the big job that was expected from them in Paris. With or without the election of Mr. Trump, it's very clear they will all play a different role now. They'll fine-tune the rule books, but they cannot deliver the speed and scale. That's for the real economy actors, what I call the engine room: the private sector, subnational governments, investors and everyone else who is much closer to the emissions reductions themselves. That's why I'm down in the engine room now, with those who are directly responsible for the real work. It doesn't really have anything to do with Trump.

Recent studies suggest that giving women better access to education and reproductive freedom could have the single biggest impact on decarbonization. How does agency mitigate climate change?

One of the mistakes we've made as humans is not realizing that in the end, everything is interconnected. It's easier to look at large single sources, like heavy industry, rather than disseminated small sources of emissions. We look at the big head, which is power plants or transportation systems. But when you look at the long tail, it's clear that women have an important role in bringing down emissions because of the influence they have in the use of land, in food security, obviously in reproduction, and, of course, their contributions to modeling and forecasts, and as architects of adaptation strategies.

Assume two billion more people on this planet with all of the consequent impact that that's going to have. If women are given the ability to choose their reproductive behavior more intentionally, then we might have a different number. The better the quality of life of women through education, decisions over their own bodies, access to sustainable food production and clean energy technologies, the better we'll do with emissions.

After your tenure, more women are in positions of power at the U.N. But when it comes to negotiating climate solutions at large, there's criticism that it's not enough. What's your reaction to this?

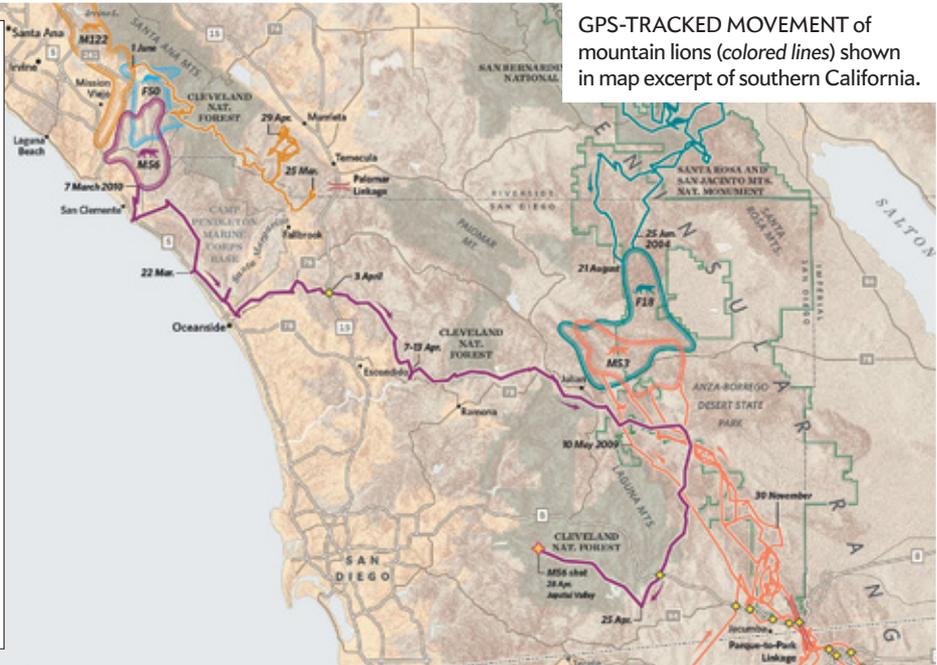
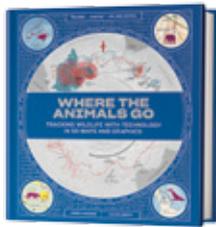
I've become very intolerant of rooms, panels, photos, whatever, that have a huge preponderance of men. I was recently at an event that was 28 men and me. I used my keynote—as I often do—to point out how this is just not acceptable. I go, "Good morning, everyone. What's wrong with this room?" And then I'm silent and let them figure it out. Very often they don't even know what the heck I'm talking about. But I think we have to call it out constantly. Because otherwise we don't startle people out of the default. Making people feel uncomfortable is the only way things are going to change. ■

RECOMMENDED

By Andrea Gawrylewski

Where the Animals Go:

Tracking Wildlife with Technology in 50 Maps and Graphics
by James Cheshire and Oliver Uberti.
W. W. Norton, 2017 (\$39.95)



GPS-TRACKED MOVEMENT of mountain lions (colored lines) shown in map excerpt of southern California.

For all we know about animals, we know relatively little about their travel habits. New tracking technologies are quickly filling in this information gap, giving biologists insights about animal foraging, mating, migration, and more. Geographer Cheshire and designer Uberti teamed up to collect the stories of scientists who are tracking animals and to illustrate the maps of those animals' daily routes. The result is a stunning translation of movement onto paper: penguin nesting sites gathered from satellites; the restricted territories of mountain lions boxed in by freeways in California; the daily flight of an average bumblebee in Germany. The animal that inspired the book, however, has a sad story. She was an elephant named Annie whose GPS collar logged her 1,000-mile-plus journey over the course of 12 weeks in eastern Chad until she was brought down by poachers.

Making Contact: Jill Tarter and the Search for Extraterrestrial Intelligence

by Sarah Scoles. Pegasus Books, 2017 (\$27.95)



Jill Tarter, the astronomer who overcame rampant sexism to become a global leader in the hunt for radio messages from aliens, is a household name among the science-interested set. Many know her as the real-life model for Jodie Foster's character in the blockbuster movie adaptation of Carl Sagan's 1985 novel, *Contact*. Tarter famously avoids self-promotion, so for most of us she is far from familiar. Journalist Scoles's intimate biography—the first ever about Tarter and written with her full cooperation—could change that. Her story is inextricably intertwined with the past, present and future of our search for life around distant stars, but its core is more about “a fierce, determined, stubborn, smart woman who asked big questions about the universe and didn't hear ‘No’ as ‘No’ but as ‘Keep trying.’”

—Lee Billings

Dinner with Darwin: Food, Drink, and Evolution

by Jonathan Silvertown. University of Chicago Press, 2017 (\$27.50)



Evolutionary ecologist Silvertown knows how old your food is. He knows who in history ate it first and why humans pursued each particular form

of sustenance. People have spent millennia altering food's attributes to complement our digestive tracts and lifestyles. Silvertown breaks down the sociology, selective breeding and nutritional evolution behind each contemporary dietary staple. Bread, for example, was perfected after centuries spent plucking only the best wild grasses. Humans have adapted to foods as well: we came to love spice plants such as thyme and rosemary in spite of their chemical defenses, which other animals do not tolerate. This tour—from animal to vegetable to beer—will give even the most ambitious foodie something to chew on.

—Leslie Nemo

Significant Figures: The Lives and Work of Great Mathematicians

by Ian Stewart. Basic Books, 2017 (\$27)



In the third century A.D., Chinese mathematician Liu Hui proved the Pythagorean theorem hundreds of years before the ancient Greek, the more famous eponymous author of the proof, was born. Around 1400 a poem by Indian mathematician Madhava of Sangamagrama used “gods,” “elephants” and “snakes” to symbolize numbers to approximate the value of pi. Sofia Kovalevskaja, the second woman ever to receive a Ph.D. in math, made breakthroughs in partial differential equations and mechanics in 19th-century Europe—inspired by nursery wallpaper made from pages of a calculus textbook. These biographies and more illustrate the history—and personalities—of mathematics. As Stewart, a mathematician himself, writes: “Mathematics doesn't arise in a vacuum: it's created by people.”

—Clara Moskowitz

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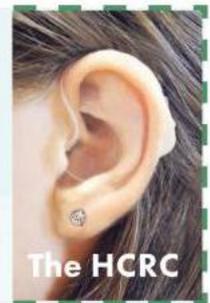
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Michael Shermer is publisher of *Skeptic* magazine (www.skeptic.com) and a Presidential Fellow at Chapman University. His next book is *Heavens on Earth*. Follow him on Twitter @michaelshermer

Postmodernism vs. Science

The roots of the current campus madness

By Michael Shermer

In a 1946 essay in the *London Tribune* entitled “In Front of Your Nose,” George Orwell noted that “we are all capable of believing things which we *know* to be untrue, and then, when we are finally proved wrong, impudently twisting the facts so as to show that we were right. Intellectually, it is possible to carry on this process for an indefinite time: the only check on it is that sooner or later a false belief bumps up against solid reality, usually on a battlefield.”

The intellectual battlefields today are on college campuses, where students’ deep convictions about race, ethnicity, gender and sexual orientation and their social justice antipathy toward capitalism, imperialism, racism, white privilege, misogyny and “cissexist heteropatriarchy” have bumped up against the reality of contradictory facts and opposing views, leading to campus chaos and even violence. Students at the University of California, Berkeley, and outside agitators, for example, rioted at the mere mention that conservative firebrands Milo Yiannopoulos and Ann Coulter had been invited to speak (in the end, they never did). Middle-

speak—or to be—must never be based on skin color.” In response, an angry mob of 50 students disrupted his biology class, surrounded him, called him a racist and insisted that he resign. He claims that campus police informed him that the college president told them to stand down, but he has been forced to stay off campus for his safety’s sake.

How has it come to this? One of many trends was identified by Weinstein in a *Wall Street Journal* essay: “The button-down empirical and deductive fields, including all the hard sciences, have lived side by side with ‘critical theory,’ postmodernism and its perception-based relatives. Since the creation in 1960s and ’70s of novel, justice-oriented fields, these incompatible world-views have repelled one another.”

In an article for *Quillette.com* on “Methods Behind the Campus Madness,” graduate researcher Sumantra Maitra of the University of Nottingham in England reported that 12 of the 13 academics at U.C. Berkeley who signed a letter to the chancellor protesting Yiannopoulos were from “Critical theory, Gender studies and Post-Colonial/Postmodernist/Marxist background.” This is a shift in Marxist theory from class conflict to identity politics conflict; instead of judging people by the content of their character, they are now to be judged by the color of their skin (or their ethnicity, gender, sexual orientation, et cetera). “Postmodernists have tried to hijack biology, have taken over large parts of political science, almost all of anthropology, history and English,” Maitra concludes, “and have proliferated self-referential journals, citation circles, non-replicable research, and the curtailing of nuanced debate through activism and marches, instigating a bunch of gullible students to intimidate any opposing ideas.”

Students are being taught by these postmodern professors that there is no truth, that science and empirical facts are tools of oppression by the white patriarchy, and that nearly everyone in America is racist and bigoted, including their own professors, most of whom are liberals or progressives devoted to fighting these social ills. Of the 58 Evergreen faculty members who signed a statement “in solidarity with students” calling for disciplinary action against Weinstein for “endangering” the community by granting interviews in the national media, I tallied only seven from the sciences. Most specialize in English, literature, the arts, humanities, cultural studies, women’s studies, media studies, and “quotidian imperialisms, intermetropolitan geography [and] detournement.” A course called “Fantastic Resistances” was described as a “training dojo for aspiring ‘social justice warriors’” that focuses on “power asymmetries.”

If you teach students to be warriors against all power asymmetries, don’t be surprised when they turn on their professors and administrators. This is what happens when you separate facts from values, empiricism from morality, science from the humanities. ■



bury College students physically attacked libertarian author Charles Murray and his liberal host, professor Allison Stanger, pulling her hair, twisting her neck and sending her to the ER.

One underlying cause of this troubling situation may be found in what happened at Evergreen State College in Olympia, Wash., in May, when biologist and self-identified “deeply progressive” professor Bret Weinstein refused to participate in a “Day of Absence” in which “white students, staff and faculty will be invited to leave the campus for the day’s activities.” Weinstein objected, writing in an e-mail: “on a college campus, one’s right to

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Steve Mirsky has been writing the Anti Gravity column since a typical tectonic plate was about 36 inches from its current location. He also hosts the *Scientific American* podcast Science Talk.

The Face of Evil

Not every movie villain has terrible skin, but it helps

By Steve Mirsky

In 2003 a committee assembled by the American Film Institute (AFI) compiled a new list for movie fans to digest and argue about. The institute had previously released lists of the 100 best movies, 100 funniest comedies, 100 most exciting thrillers, 100 most passionate love stories and 50 greatest movie stars (who were announced by 50 other movie stars, which let the AFI put “100 Stars” in the title because that was the formula, dammit). The new collection was the 100 top heroes and villains, with 50 for each archetype. CBS ran a three-hour TV special about the selections, after which the list receded from the public consciousness.

Until just a few months ago: in June the heroes-and-villains list was considered anew in a national publication. *Entertainment Weekly*? No. *Variety*? No. *Rolling Stone* or *Vanity Fair*? No and no. To find the analysis, pick up a copy of *JAMA Dermatology*.

The investigation, entitled “Dermatologic Features of Classic Movie Villains: The Face of Evil,” was carried out by Julie Amthor Croley and Richard F. Wagner, both at the department of dermatology at the University of Texas Medical Branch at Galveston, and Vail Reese of Union Square Dermatology in San Francisco. The conclusion: “Classic film villains display a statistically significant higher incidence of dermatologic findings than heroes.” In other words, lots of bad guys have bad skin. In other other words, that white hat typically sits atop a flawless (and also white) complexion.

The researchers concentrated on the top 10 members of the two lists and found that “six of the all-time top 10 American film

villains (60%) have dermatologic findings, all ... located on the face and scalp.” None of the top heroes display any conspicuous facial flaws—because they’re heroes.

For example, when we finally see the face of Sebastian Shaw’s Darth Vader (all-time villain number three), we’re treated to “scars on left cheek and scalp vertex, deep rhytides on face, periorbital hyperpigmentation, alopecia.” In plain English, that’s scars, creases, dark circles around the eyes, hair loss. Meanwhile number-three hero James Bond, as portrayed by Sean Connery, has virtually perfect skin despite a lifestyle of dubious choices in terms of alcohol intake and exposure to sexually transmitted diseases.

Or take villain number 10, the animated Queen in *Snow White and the Seven Dwarfs*, who has “rhinophyma [big bumpy nose], deep rhytides on face, verruca vulgaris [a wart] on nasal dorsum, periorbital hyperpigmentation.” Hero number 10, Peter O’Toole’s Lawrence of Arabia, runs around the desert for months without suffering so much as a mild sunburn.

One more comparison: hero number four, Humphrey Bogart’s café-owning Rick Blaine in *Casablanca*, has a slight scar on his lip. But, the authors note, “facial scars of the heroes are much subtler and shorter in length than those of the villains. Unlike the scars of the villains, those of the heroes are neither created with prosthetic makeup nor commented on during the narrative.” (That is, Rick had a scar because Bogie did.) Compare Rick with the fourth-rated villain, Margaret Hamilton’s Wicked Witch of the West in *The Wizard of Oz*. She sports a prominent wart on the right side of her chin. Also, she’s freaking green.

That baddies have blemishes is, unlike their appearance, clear—but is it a big deal? The researchers think it might be: “The results of this study demonstrate Hollywood’s tendency to depict skin disease in an evil context, the implications of which extend beyond the theater. Specifically, unfairly targeting dermatologic minorities may contribute to a tendency toward prejudice in our culture and facilitate misunderstanding of particular disease entities among the general public.” In real life, verruca vulgaris is not a manifestation of malevolence.

This subject hits me personally, as I have what an old ad campaign called the “heartbreak of psoriasis.” And I am, as far as I’m able to tell, not evil. But I admit that my condition may inform my choice of favorite movie hero, a freak without a film franchise when the AFI’s list came out. I’m thinking, of course, of Ryan Reynolds’s hot mess, Deadpool. The pockmarked protagonist says to the integumentally imperfect that we, too, have skin in the game. ■

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Smart Partnerships

The new biotechnology park in Riyadh bridges the gap between the biomedical research in the region and commercial opportunities afforded by extensive research. Smart partnerships help channel the ingenuity of researchers, to develop solutions that address local and regional health issues.

Read more on KAIMRC Innovations' efforts to build mutually beneficial and sustainable partnerships.

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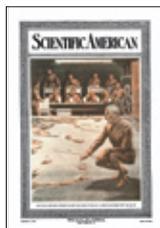
SEPTEMBER

1967 Solid-State Science

“If you take a paper clip and bend it, it stays bent; it doesn’t spring back and it doesn’t break. The metal of which the clip is made is said to be ductile. If you try to bend a glass rod (unless you are holding it in a flame), it will simply break. It is said to be brittle. In this respect, as in many others, glass behaves quite differently from a metal. The difference must lie either in the particular atoms of which metals and glass are made up or in the way they are put together—probably both. Students of such matters naturally want to understand the reasons for these differences in behavior. During the past 20 years studies of this kind have been called solid-state physics, or sometimes, since the subject includes a great deal of chemistry, just ‘solid state.’ It is a major branch of science that has revealed new and previously unsuspected properties in materials. An example is the properties of semiconductors, knowledge of which has given rise to a flood of technological devices such as the transistor. —Sir Nevill Mott”
Mott shared the 1977 Nobel Prize in Physics for his research on materials.



1967



1917



1867

spurt from the vessel’s side, deflecting and pushing away the torpedo and thus saving the vessel. He didn’t calculate that the jets he proposed required some ten thousand horsepower for their making, enough to power several merchant ships.”

1867 Fire Engines

“Although hand engines for extinguishing fires are still largely employed in this country, the cities and large towns have generally adopted the much more effective steamer, with its muscles of iron and steel, which never tire. The New York ‘Metropolitan Fire Department’ has no less than thirty-four engines, the subject of our engraving being one of them.”

Archive images of other technologies from 1867 are at www.ScientificAmerican.com/sep2017/technology-1867

Emperor of Agriculture

“Mr. McCormick having accepted an invitation from the Emperor Napoleon to give a private exhibition of the working of his reaping machine, a trial was made a short time since on the Imperial farm near Chalons, at which the Emperor was present, accompanied by Marshal Neil, General Le Boeuf and Eugene Tisseraud, Director General of the Imperial Agricultural Estates. The trial was a complete success, and gave so

much satisfaction to the Emperor that he immediately gave orders for the purchase of three of the machines for use on his private farms, and earnestly expressed the intention of encouraging the adoption of the invention throughout France, on account of its great labor-saving properties, and said that he would set the example by putting it in operation on all imperial farms.”

A Theory on Pyramids

“For several thousand years the object for which the ‘Great Pyramid’ was constructed was a mystery to the whole world, and many of the most learned *savans* have exhausted surmise and speculation in their fruitless efforts to solve the riddle. A gentleman in London, Mr. Thomas Taylor, conceived the idea that the structure was inspired by Divine Providence to afford the Egyptians a standard for their weights and measures. This theory, fanciful and far-fetched as it is, has recently found an advocate on this side of the water, in the person of Professor Eaton, of New York, who read an elaborate essay on the subject before the University Convocation at Albany. Professor Eaton proceeded to show that the temperature of the central room was uniform throughout, thus affording a place for keeping weights and measures.”

1917 Ideas That Will Not Work

“There are literally thousands of plans, suggestions, inventions, drawings, models, devices, ideas, pouring into the government all the time, all bearing on the war, and most of them on the submarine problem. A good illustration of clever but impractical ideas is found in the proposal of a capable man who worked out and sent in a scheme to protect hulls from submarines by jets of water. Anyone who has ever stood near the nozzle of a fire engine hose realizes the tremendous blow which a swiftly moving, broad jet of water can strike. This inventor proposed a series of such jets, which would



1867: Modern steam-powered fire engine of New York City’s Metropolitan Fire Department.



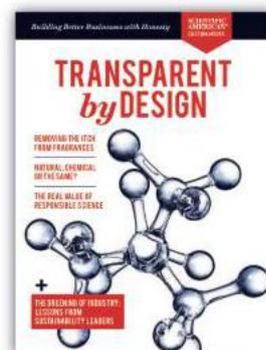
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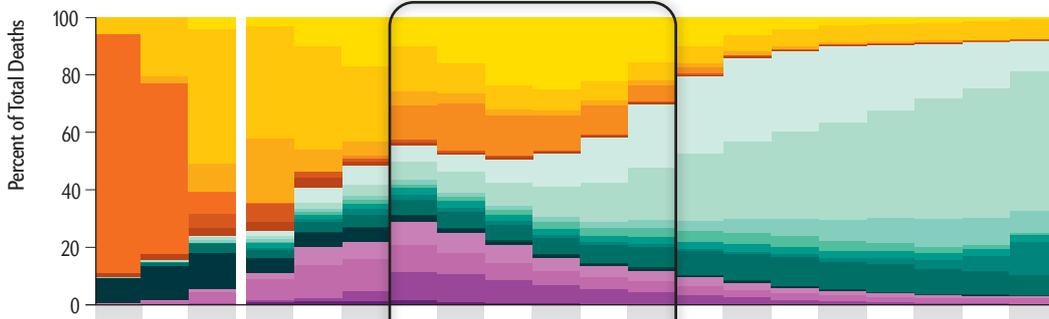
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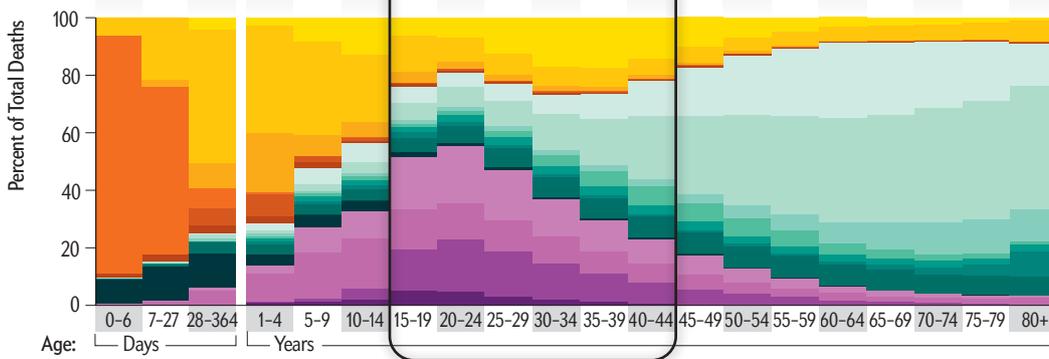

A FAMILY COMPANY



Women: Causes of Death Worldwide (2015)



Men: Causes of Death Worldwide (2015)



- Communicable, Maternal, Neonatal and Nutritional Causes**
- HIV/AIDS, tuberculosis
 - Diarrhea, respiratory illness
 - Malaria, tropical disease
 - Maternal disorders
 - Neonatal disorders
 - Nutritional deficiencies
 - Other disease
- Noncommunicable Causes**
- Tumors, cancer
 - Cardiovascular disease
 - Pneumonia, asthma
 - Liver disease
 - Digestive tract disease
 - Neurological disorders
 - Mental illness, substances
 - Diabetes, blood disease
 - Musculoskeletal disorders
 - Congenital, skin disorders
- Injuries**
- Transportation injuries
 - Other accidents
 - Self-harm and violence
 - War and disaster

The End

What do most women and men die of?

Cause of death diverges most between women and men aged 15 to 45. The disparity is largely driven by mortality rates in underdeveloped countries; differences in developed countries are much less pronounced.

It may be uncomfortable to ponder, but elderly ladies and gentlemen worldwide die of very similar causes, notably cardiovascular disease. Girls and boys also succumb to a similar set of illnesses, mostly infectious diseases. Yet the death differences are pronounced for young and middle-aged women and men, according to the Institute for Health Metrics and Evaluation in Seattle (*large graphic*). Women are more likely to die from tuberculosis, diarrhea, respiratory illnesses and nutritional deficiencies. Men perish from substance abuse, injuries, self-harm and violence. As with so many issues related to the sexes, cause of death is determined much more by social factors than by biology (*small graphs*). —Mark Fischetti

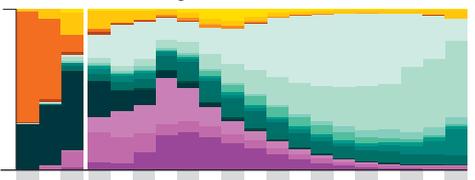
Social Influences

Compared with worldwide averages, many more women and men die of disease in countries with a depressed socioeconomic index (SDI)—a combination of low income and education levels and high fertility rates. More women and men die from injuries and violence in countries with an elevated SDI—high income and education and low fertility.

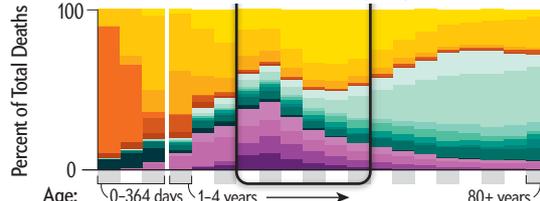
Women: Deaths in Low-SDI Countries (2015)



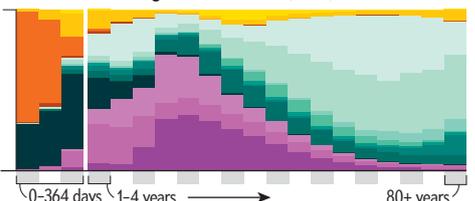
Women: Deaths in High-SDI Countries (2015)



Men: Deaths in Low-SDI Countries (2015)



Men: Deaths in High-SDI Countries (2015)



SOURCE: "GBD COMPARE" BY INSTITUTE FOR HEALTH METRICS AND EVALUATION, UNIVERSITY OF WASHINGTON, 2017. ACCESSED JULY 2017. <http://vizhub.healthdata.org/gbd-compare>

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“David Birnbaum Cracks the Cosmic Code”

see full-length feature article in

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