Neuroscience Fiction and Fact | Hope Fades for Planet Nine

ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE ■ MARCH 13, 2021

Race and Genetics

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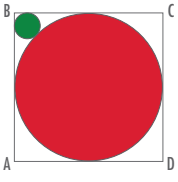

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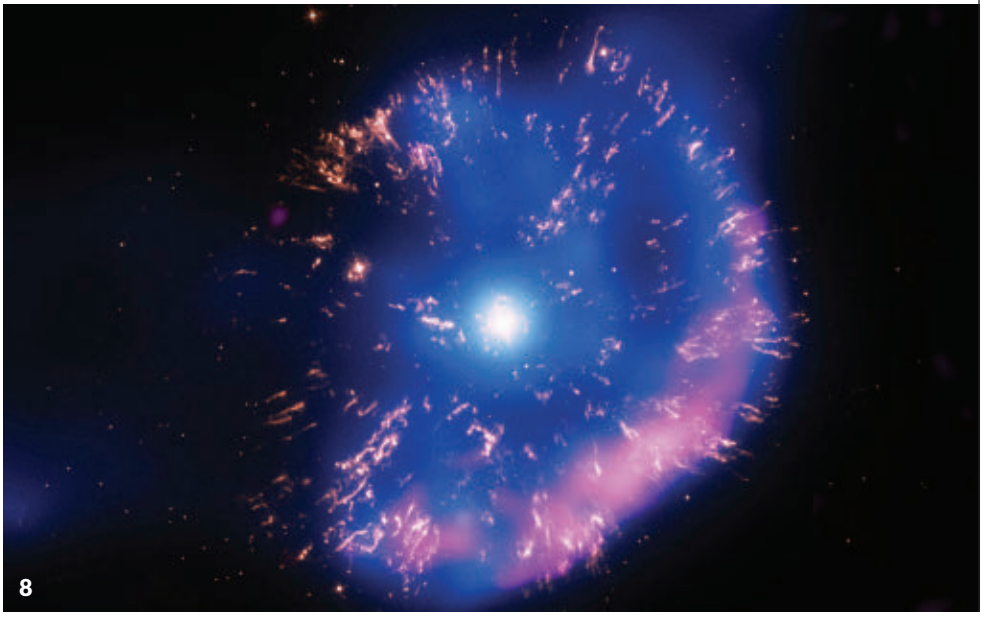
Features

News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Departments

COVER Expanding DNA databases to include a broader mix of people may reveal more variants relevant to some common diseases. *Delphine Lee*

FROM TOP: GLENN HARVEY; MARTINA CECCHETTI; D. TAKEI *ET AL*, NASA, CXC, RIKEN (X-RAY), STSCI, NASA (OPTICAL), VLA/NRAO (RADIO)

Genetic medicine is fraught with ethical challenges

Twenty years ago, the Human Genome Project unveiled the first map of humankind's genetic instructions, an astonishing feat of technology that promised a future of medical treatments tailored to the quirks of a person's DNA.

Since then, researchers have vastly increased our knowledge of how genes work and realized that there's still a lot we don't know about life's blueprints. And though many drugs designed to target specific human genes or proteins have been approved, for most people the promise of precision medicine is still no more than that — a promise.

One reason is that the human reference genome and other genetic catalogs don't reflect the diversity of humankind — most of the DNA is from people of European heritage. In many cases, that's not a factor, but with some medical treatments, the differences can be crucial, as senior writer Tina Hesman Saey reports in this issue (Page 24). Suggested approaches to make up for those shortcomings are fraught with ethical challenges.

As part of our project exploring the ethics of cutting-edge scientific research, Saey sought out researchers trying to find solutions to the problem of genetic databases dominated by samples from white people. One of those researchers is Constance Hilliard, an evolutionary historian at the University of North Texas in Denton, who points out that many scientists tend to assume that everyone on a continent is the same, and thus may miss how humans adapted to local conditions.

A key goal of this reporting project, which is funded by the Kavli Foundation, is to let the public be a part of the conversation, including using readers' comments to inform the questions that our reporters ask scientists. So back in November, we posted a short video of Hilliard explaining her views and asked people what they thought about her proposal to diversify genetic databases.

Respondents overwhelmingly agreed that genetic research is important for advancing medical care, but many also expressed worry that emphasizing genetic differences could lead to more discrimination. There's a long, tragic history of such efforts, and they continue today. As one reader commented: "The fear is that any differences that are found would be exploited by those who want to denigrate others."

It's crucial to bring up these ethical questions and think deeply about them before science happens, Saey told me. "What's the best way to proceed — not just the best scientific way to proceed, but the most ethical and fair way to go forward?" she asked. "Or maybe decide it's not ethical and fair to go forward, and then we decide what to do with that."

We'd like you to continue to be part of this conversation. Please read Saey's story and e-mail us at feedback@sciencenews.org. We'll report back on what we hear from readers and hope to continue these conversations. Modern science is a powerful force for good. But even unintentional harms can have seismic impacts, especially in an era when science is doubted and even demonized by some. — *Nancy Shute, Editor in Chief*

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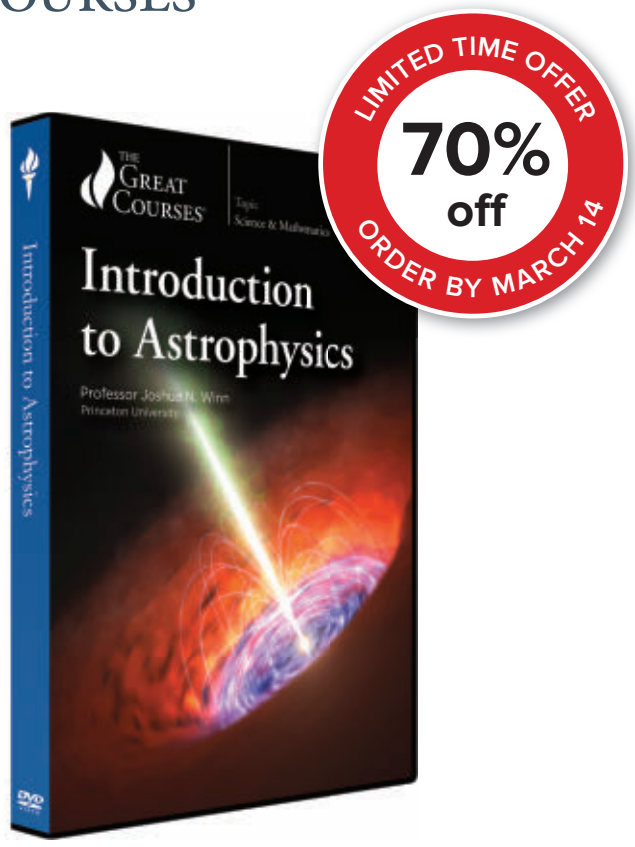

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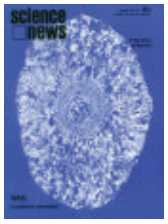


Excerpt from the March 20, 1971 issue of *Science News*

50 YEARS AGO

Fooling the brain

Chronic pain can be treated surgically by severing nerves or by destroying a small part of the brain that perceives pain, but these methods are destructive. Doctors ... are now treating selected cases of chronic pain ... by using electrical impulses [on the spinal cord] to fool the brain.

UPDATE: In 1971, the idea to treat chronic pain by sending electrical impulses to the spinal cord was not brand-new. Researchers tested the first implantable device in patients in the United States in 1967. Such implants gained momentum as a pain treatment in the 1970s, and the U.S. Food and Drug Administration approved the technique in 1989. Technological advances in the decades since have led to more effective and precise devices. One stimulator interacts with cells in the spinal cord to adjust the amount of electricity based on a patient's needs, researchers reported in 2020. But spinal cord stimulation can do more than relieve pain: Sending impulses to specific nerve cells at precise times has been shown to help people paralyzed by severe injuries walk again (*SN: 11/24/18, p. 6*).

Playing with a cat that spends time outdoors in a way that mimics hunting, such as with a feather toy, might lessen the feline's impact on wildlife.

FOR DAILY USE

Meatier meals and more playtime might reduce cats' toll on wildlife

Surprisingly simple measures might keep domestic cats from killing a lot of wildlife.

Estimates vary, but it's likely that billions of birds and mammals succumb each year to our outdoor-ranging feline friends (*SN: 2/23/13, p. 14*). Calls to keep cats indoors are often contentious among cat owners, and cats can sometimes reject colorful collars or loud bells designed to make them more noticeable. But a meat-rich diet or a few minutes of hunting-like play each day can significantly reduce the amount of wildlife cats bring home, researchers report online February 11 in *Current Biology*.

Most attempts to curb cats' impact on wildlife have focused on restricting the animals' behavior and ability to hunt. Ecologist Robbie McDonald of the University of Exeter in Cornwall, England, and colleagues investigated the root of the problem: the urge to hunt in the first place. "We wanted to find out why well-fed cats might still kill wildlife," he says.

This urge might stem from natural instincts or cats' need to supplement their diet, the team reasoned. So the researchers tested food and play interventions on 355 domestic cats in 219 households in southwest England. Only known hunters were enrolled; owners tallied up every critter their cats brought home for seven weeks to establish a baseline for each cat.

Owners then implemented one intervention for six weeks: switching to a high-meat commercially available food; playing for five to 10 minutes daily; putting their cat's normal food in a puzzle feeder; and affixing bells or brightly colored collars that warn birds that cats are near.

Cats fed the meat-rich diet brought home 36 percent less prey, on average, than they did before the diet change. "This might not seem like very much," McDonald says. But "a very large cat population means that if this average were applied across the board, it would result in very many millions fewer deaths." Felines treated to playtime with feather and mouse toys returned 25 percent less prey, a drop that came mostly from mammals. Cats that used puzzle feeders brought home more wildlife. Bells had no effect. Collared cats returned 42 percent fewer birds, but roughly the same number of mammals.

"It's a robust study that I hope is followed up with more research," says ecologist Susan Willson of St. Lawrence University in Canton, N.Y. Because the study focused on prey brought home, it could be missing wildlife killed and eaten or left outside, she says.

Keeping cats indoors is the surest way to prevent them from killing wildlife, though some owners bristle at this advice. McDonald contends the study's tactics were less contentious. He hopes that cat owners will consider trying the changes. "It's good for conservation and good for cats." — *Jonathan Lambert*

MARTINA CECCHETTI

TEASER

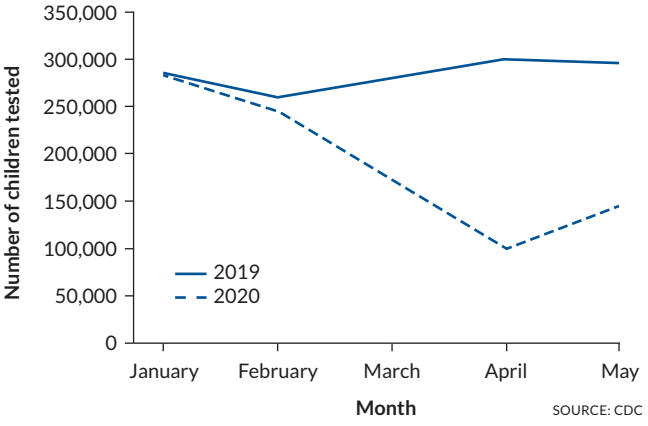
Tiny aircraft that fly by light could soar beyond airplanes' reach

Flight isn't easy at the edge of space. But tiny microfliers could soar high in Earth's atmosphere fueled only by sunlight, experiments suggest.

At heights between about 50 and 80 kilometers above Earth's surface, in what's called the mesosphere, air is so thin that airplanes and balloons can't stay aloft. But mechanical engineer Mohsen Azadi and colleagues at the University of Pennsylvania saw promise in levitating objects with light. When heated by light, 6-millimeter-wide disks of Mylar coated in carbon nanotubes floated inside a chamber pressurized to mimic the mesosphere. Such microfliers could run on sunlight or laser light and could someday carry instruments to explore the mesosphere, the team reports February 12 in *Science Advances*.

Carbon nanotubes are key for the microfliers to achieve liftoff. The nanotubes absorb light, warming the flier. When air molecules collide with the warmed flier, they gain energy and ricochet away from it at high speeds. The molecules that strike the carbon nanotubes on the aircraft's bottom get extra oomph thanks to the material's nooks and crannies: Air molecules that collide multiple times with the nanotubes get even warmer and gain more energy, ricocheting away faster than the molecules from the top, generating lift. — *Emily Conover*

Blood lead level testing of U.S. children under 6 years old, January–May 2019 and January–May 2020



SOURCE: CDC

SCIENCE STATS

Child lead testing plummeted in 2020

Close to a half million U.S. children didn't get tested for lead in the first half of 2020 — a troubling indicator of the preventive medical care that kids haven't received since the pandemic began. Data from 34 state and local health departments reveal that 480,172 fewer children were tested for lead from January through May 2020 compared with that time period in 2019 (see graph above), researchers report in the Feb. 5 *Morbidity and Mortality Weekly Report*. Those missed tests left an estimated 9,603 kids with elevated lead levels in their blood unidentified. — *Aimee Cunningham*

INTRODUCING

A new chameleon species is extremely compact

Hidden beneath the leaf litter of a northern Malagasy forest lives a chameleon so slight that it could tumble off the tip of your finger. Measuring just under 30 millimeters from snout to tail, the newly described species, *Brookesia nana*, may be the smallest reptile on Earth, researchers report January 28 in *Scientific Reports*.

Just two adult specimens, a male and female, are known. The female measures 28.9 millimeters, much larger than the 21.6-millimeter-long male. The size difference may have driven the male's genitalia to be quite large — nearly 20 percent of its body length — to be a better fit to his mate, herpetologist Frank Glaw of the Bavarian State Collection of Zoology in Munich and colleagues suggest.

Dubbed *B. nana* for its nanosize, the species belongs to a genus of at least 13 small chameleons spread out across the mountainous forests of northern Madagascar. Why *B. nana* and its cousins shrank to such minuscule proportions remains a mystery, though smallness does have its benefits: There's some evidence that small chameleons are especially good shots with their ballistic tongues.

In daylight, *Brookesia* chameleons scour the forest floor, snatching up mites and other small invertebrates, Glaw's team suspects. At night, the lizards retreat upward, gripping blades of grass or other plants for safety.

Deforestation and habitat degradation threaten *B. nana*'s future, the researchers say, though the region where the compact chameleons were found was recently designated a protected area by the Malagasy government. The species may soon be listed as critically endangered, among the gravest ratings from the International Union for Conservation of Nature. — *Jonathan Lambert*

Meet *Brookesia nana*, potentially the world's smallest reptile. This chameleon, found in northern Madagascar, is tiny enough to comfortably fit on the tip of a person's finger.

FROM TOP: C. CHANG; F. GLAW/ZSM/SNSB

Watch microfliers take off at **bit.ly/SN_Microflier**

Mammoths (illustrated) already had shaggy hair and other cold adaptations by 1 million years ago, a new study of ancient DNA suggests.

GENES & CELLS

Million-year-old mammoth DNA found

Oldest animal DNA yet recovered comes from Siberian fossils

BY ERIN GARCIA DE JESUS

The oldest DNA ever recovered from an animal is adding new chapters to mammoth life history, going back more than 1 million years.

Genetic material from ancient mammoth molars found in Siberia handily beats the previous record set by 700,000-year-old DNA from a frozen, fossilized horse (*SN: 7/27/13, p. 5*). Some gene snippets from the newly recovered DNA suggest that ancient mammoths already had the traits that allowed them to withstand low temperatures during later ice ages. What's more, some hairy behemoths that inhabited North America may have been a hybrid of the woolly mammoth and a previously unknown lineage of mammoths, researchers report online February 17 in *Nature*.

The findings "really highlight the exciting times that we live in," says Charlotte Lindqvist, an evolutionary biologist at the University at Buffalo in New York who was not involved in the work. "We can get genetic data — we can recover DNA — from such ancient samples that can directly give us windows into the past." Such data can reveal how extinct animals evolved, adding to the clues that come from physically examining bones.

The mammoth DNA was extracted from three molars unearthed in the 1970s from permafrost in northeastern Siberia. Though DNA degrades into shorter strings of genetic material over time, making it difficult to handle and piece together, cold permafrost helps to protect genetic information from rapidly falling apart. Theoretical studies had suggested that researchers could perhaps recover DNA older than 1 million years. Still, the preserved mammoth DNA is "quite close to the limit of what is possible," says Love Dalén, an evolutionary geneticist at the Centre for Palaeogenetics in Stockholm.

The two oldest specimens, dubbed Krestovka and Adycha, date to about 1.2 million to 1 million years ago, Dalén and colleagues found. The third, called Chukochya, dates back 800,000 to 500,000 years. Genetic analyses of DNA recovered from these specimens — as well as DNA from other mammoths and present-day elephants — suggest that Krestovka and Adycha belonged to two different mammoth lineages. Researchers had previously thought that only one type of mammoth, called the steppe mammoth (*Mammuthus trogontherii*), lived in Siberia 1 million years ago.

While Adycha was part of the steppe mammoth lineage that eventually gave rise to woolly mammoths, the Krestovka mammoth may have diverged from its relatives more than 2 million years ago and could represent an unknown line of mammoths, the researchers say. That unidentified lineage might have mixed with woolly mammoths at least 420,000 years ago to give rise to the Columbian mammoth (*M. columbi*), which roamed North America. The younger Chukochya may have been an early woolly mammoth (*M. primigenius*).

The newly decoded genetic material expands the geographic range where such mammoth samples have come from, says Vincent Lynch, an evolutionary biologist at the University at Buffalo who was not involved in the work. Analyzing the genetics of many mammoths from varied locations, he says, is "important if you want to make statements about how mammoths came to be mammoths, why they look the way they do and how diverse they were."

Traits such as shaggy hair, which probably helped mammoths handle the cold, are ancient, the team found. The Adycha and Chukochya mammoths already had the genetic tweaks for many of these traits, hinting that the hairy animals adapted slowly to the chill of ice ages over hundreds of thousands of years. "A lot of the mutations which we think make mammoths mammoths — small ears, lots of fat, not sensitive to cold — happened before they got into that environment," Lynch says.

Still, while the results are intriguing, DNA is fragile, and there's a limit to how much data scientists can get from old specimens, Lindqvist says. So the findings are unlikely to be the full story. ■

BETH ZAIKEN/CENTRE FOR PALAEOGENETICS

HUMANS & SOCIETY

Nonwhite police officers use force less often

Diversifying the police may improve treatment of civilians

BY MARIA TEMMING

Black and Hispanic police officers are less likely to stop, arrest and use force against civilians, especially Black civilians, than white officers, a case study of the Chicago Police Department suggests. And female officers of all races use less force than their male colleagues.

Information on the demographics and behavior of thousands of Chicago police officers revealed how officers of different races and genders acted while on similar patrol assignments. While the results do not shed light on why these differences exist, they do suggest that diversifying U.S. police departments — which have historically been nearly all white and male — may improve police treatment of minority communities, researchers report in the Feb. 12 *Science*.

"When I got the paper, I literally at one point said, 'Hot damn,'" says behavioral scientist Phillip Goff of Yale University, who wrote a commentary on the study for the same issue of *Science*. "I was a skeptic about demographic reform previously, and now I am a convert.... Demographics reform in policing actually has the potential to dramatically change behavior."

Diversifying law enforcement is one of the most frequently proposed police reforms, Bocar Ba, an economist at the University of California, Irvine, said in a February 8 news conference at the virtual annual meeting of the American Association for the Advancement of Science. Calls for changes to law enforcement have been particularly prominent in the last year, in response to the police killings of George Floyd and other Black civilians. But so far, research has not provided clear answers about proposed reforms (*SN: 8/15/20, p. 10*).

The problem has been a lack of available data, Ba said. Over three years, he and colleagues peppered various agencies with open-records requests and appeals to collect data from the Chicago Police Department. Those data included officers' race, gender and patrol assignments, as well as time-stamped and location-tagged records of when officers stopped, arrested or used force on civilians.

In total, the team examined 2.9 million officer shifts and 1.6 million enforcement activities performed by nearly 7,000 officers from 2012 to 2015. The team looked at how officers of different races and genders behaved while patrolling the same neighborhood at the same time of day, day of the week, month and year.

Black officers made 15.16 fewer stops, 1.93 fewer arrests and used force 0.1 fewer times than their white counterparts, on average, over the course of 100 shifts. That corresponded to a 29 percent reduction in stops, 21 percent reduction in arrests and 32 percent reduction in use of force among Black officers, compared with the average enforcement rates among their white peers.

Those differences arose primarily because Black officers were less likely to stop and use force against Black civilians. Black officers also relied less on discretionary enforcement activities, like stopping people for "suspicious behavior," and focused less on petty crimes, such as drug offenses. Black and white officers' arrest rates for violent crime were more similar.

Hispanic officers also made fewer stops, made fewer arrests and used force less often than white officers, though the difference was not as stark. Hispanic officers made 2.84 fewer stops, 0.44 fewer arrests and 0.04 fewer uses of force per 100 shifts, on average. That represented a 6 percent, 5 percent and 12 percent reduction, respectively, compared with white officers' average stop, arrest and use of force rates.

Female officers of all races made 7 percent fewer arrests than their average male peers and used force 28 percent less often. Like Black officers, Hispanic and female officers were less likely than white male officers to arrest and use force against Black civilians.

The reason officers of different races and genders police differently may be due to personal biases or differing responses to training, or perhaps civilians respond differently to officers of different races or genders, says Robin Engel, a criminal justice researcher at the University of Cincinnati who wasn't involved in the work. Future research will have to dive deeper into officer-civilian interactions to tease out the reasons for these demographic differences, and investigations of police behavior in other cities will be necessary to determine whether these results hold up outside of Chicago. ■

A new case study based on Chicago police activities sheds light on how often police officers of different races and genders stop, arrest and use force on civilians during patrols.

RIVERNORTHPHOTOGRAPHY/ISTOCK UNRELEASED/GETTY IMAGES

ATOM & COSMOS

Astronomers tally up nova explosions

About four dozen of the blasts happen in the Milky Way annually

BY KEN CROSWELL

Each year, astronomers discover nova explosions in the Milky Way that cause dim stars to flare up and emit far more light than the sun before fading again. But our galaxy is so big and dusty that no one knows how many of these eruptions occur throughout its vast domain.

Now, by detecting the explosions' infrared light, which penetrates dust better than visible light does, Caltech astronomer Kishalay De and his colleagues have estimated that 46 nova explosions occur annually, give or take 13, the team reports online January 11 at arXiv.org. Past estimates have ranged from 10 to 300.

A nova typically makes a dim star shine roughly 100,000 times as brightly as the sun. Here, Nova Persei 1901 is shown in false color about a century after its explosion.

Knowing the nova rate is necessary for determining how much these explosions have contributed to the galaxy's chemical makeup by flinging newly minted elements into space.

A nova arises from a binary star, two stars circling each other. One is a white dwarf, a dense star that's about as small as Earth but about as massive as the sun. After the white dwarf receives gas from its companion, the gas explodes, making the dim star shine brilliantly. The nova does not destroy the star, unlike a supernova, which marks a star's death.

After observing the sky from Palomar Observatory in California for 17 months, De and colleagues detected 12 blasts. Estimating the number of missed outbursts, the astronomers deduced the yearly nova rate. Their rate is similar to, but more precise than, one reported four years ago that pegged the rate at between 27 and 81.

The more precise rate helps firm up estimates for how much nova explosions have altered the Milky Way's chemical composition. In this regard, it's hard for a nova to compete with a supernova, which, though rare, releases far more new elements. But if the annual nova rate is around 50, then certain scarce isotopes, or varieties of an element, on Earth — such as lithium-7, carbon-13, nitrogen-15 and oxygen-17 — arose partially or mostly in nova explosions, says Sumner Starrfield, an astronomer at Arizona State University in Tempe who wasn't involved with this study. The blasts cast out these isotopes before additional nuclear reactions could destroy them. ■

MATTER & ENERGY

Building better quantum bits

Designer molecules could improve device performance

BY EMILY CONOVER

Quantum bits made from designer molecules are coming into fashion. By carefully tailoring the composition of molecules, researchers are creating chemical systems suited to a variety of quantum tasks.

"The ability to control molecules ... makes them just a beautiful and wonderful system to work with," said Danna Freedman, a chemist at Northwestern University in Evanston, Ill. Freedman described her research February 8 at the virtual annual meeting of the American Association for the Advancement of Science.

Quantum bits, or qubits, are analogous to the bits found in conventional computers. But rather than existing in a state of either 0 or 1, as standard bits do, qubits can possess both values simultaneously, enabling new types of calculations impossible for conventional computers.

Besides their potential use in quantum computers, molecules can also serve as quantum sensors, devices that can make extremely sensitive measurements, such as sussing out minuscule electromagnetic forces.

In Freedman and colleagues' qubits, a single chromium ion, an electrically charged atom, sits at the center of the molecule. The qubit's value is represented by that chromium ion's electronic spin, a measure of the angular momentum of its electrons. Additional groups of atoms are attached to the chromium; by swapping out some of the atoms in those groups, the researchers can change the qubit's properties to alter how it functions.

Recently, Freedman and colleagues crafted molecules to fit one particular need: molecular qubits that respond to light. Lasers can set the values of the qubits and help read out the results of calculations, the researchers reported in the Dec. 11 *Science*. Another possibility is to create molecules that are biocompatible, Freedman says, so they can be used for sensing conditions inside living tissue.

Molecules have another special appeal. Many types of qubits are made from metal or other material deposited on a surface, resulting in slight differences between qubits on an atomic level. But using chemical techniques to build up molecules atom by atom means the qubits are identical, making for better-performing devices.

Scientists are already using individual atoms and ions in quantum devices, but molecules are more complicated to work with, thanks to their multiple constituents. As a result, molecules are a relatively new quantum resource, Caltech physicist Nick Hutzler said at the meeting. "People don't even really know what you can do with [molecules] yet.... But people are discovering new things every day." ■

D. TAKEI *ET AL.*, NASA, CXC, RIKEN (X-RAY), STSCI, NASA (OPTICAL), VLA/NRAO (RADIO)

ATOM & COSMOS

Planet Nine may be a mirage

A new study casts doubt on the distant world's existence

BY LISA GROSSMAN

What once looked like evidence for a giant planet hiding at the solar system's edge may be an illusion, a study suggests.

"We can't rule it out," says Kevin Napier, a physicist at the University of Michigan in Ann Arbor. "But there's not necessarily a reason to rule it in."

Previous work has suggested that a number of far-out objects in the solar system cluster in the sky as if they are being shepherded by an unseen giant planet, roughly 10 times as massive as Earth. Astronomers dubbed the invisible world Planet Nine or Planet X.

A new analysis of 14 of those bodies shows no evidence for such clustering, Napier and colleagues report online February 10 at arXiv.org in a paper to appear in the *Planetary Science Journal*.

The idea of a planet lurking far beyond Neptune received a surge in interest in 2014, when astronomers reported a collection of distant solar system bodies called trans-Neptunian objects with bunched-up orbits (*SN: 11/29/14, p. 18*).

In 2016, Mike Brown and Konstantin Batygin, both planetary scientists at Caltech, used six trans-Neptunian objects to refine the possible properties of Planet Nine, pinning it to an orbit between 500 and 600 times as far from the sun as Earth is (*SN: 7/23/16, p. 7*).

But those earlier studies all relied on just a handful of objects that may not have represented everything that's out there, says Gary Bernstein, an astronomer at the University of Pennsylvania. The objects might have seemed to show up in certain parts of the sky only because that's where astronomers happened to look.

"It's important to know what you couldn't see, in addition to what you did see," he says.

To account for that uncertainty, Napier, Bernstein and colleagues combined observations from three surveys to assess 14 trans-Neptunian objects, more than twice as many as in the 2016 study. These objects all reside between 233 and 1,560 times as far from the sun as Earth.

The team ran computer simulations of about 10 billion fake trans-Neptunian objects, distributed randomly all around the sky, and checked to see if their positions matched what the surveys should be able to see. They did.

"It really looks like we just find things where we look," Napier says. It's sort of like if you lost your keys at night and searched for them under a streetlamp, not because you thought they were there, but because that's where the light was. The study points out the streetlamps.

"Once you see where the lampposts really are, it becomes more clear that there is some serious selection bias going on with the discovery of these objects," Napier says. That means the objects are just as likely to be distributed randomly across the sky as they are to be clumped.

"On Twitter, people have been very into saying that this kills Planet Nine," Napier says. "I want to be very careful to mention that this does not kill Planet Nine. But it's not good for Planet Nine."

There are other mysteries of the solar system that Planet Nine would have neatly explained, says astronomer Samantha Lawler of the University of Regina in Canada, who was not involved with the study. A distant planet could explain why some far-out solar system objects have orbits that are tilted relative to those of the planets or where protocomets called centaurs come from (*SN: 9/12/20, p. 14*). That was part of the appeal of the Planet Nine hypothesis.

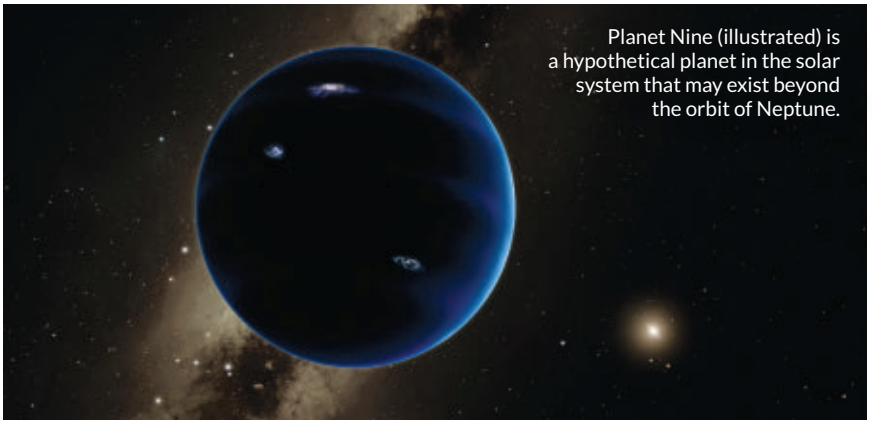
"But the entire reason for it was the clustering of these orbits," she says. "If that clustering is not real, then there's no reason to believe there is a giant planet in the distant solar system that we haven't discovered yet."

Batygin, one of the authors of the 2016 paper, isn't ready to give up. "I'm still quite optimistic about Planet Nine," he says. He compares Napier's argument to seeing a group of bears in the forest: If you see a bunch of bears to the east, you might think there was a bear cave there. "But Napier is saying the bears are all around us, because we haven't checked everywhere," Batygin says. "That logical jump is not one you can make."

Evidence for Planet Nine should show up only in the orbits of objects that are stable over billions of years, Batygin adds. But the new study, he says, is "strongly contaminated" by unstable objects — bodies that may have been nudged by Neptune and lost their position in the cluster or could be on their way to leaving the solar system entirely. "If you mix dirt with your ice cream, you're going to mostly taste dirt," he says.

Lawler says there's no consensus among researchers who study trans-Neptunian objects about which ones are stable and which ones are not.

But researchers agree that to prove Planet Nine's existence or nonexistence, astronomers need to find more of these objects. The Vera Rubin Observatory in Chile should find hundreds after it starts surveying the sky in 2023. ■



Planet Nine (illustrated) is a hypothetical planet in the solar system that may exist beyond the orbit of Neptune.

R. HURT/IPAC/CALTECH

EARTH & ENVIRONMENT

Modified genes may harm wild cotton

Introduced DNA can disrupt the plant's interactions with insects

BY EMILIANO RODRÍGUEZ MEGA

Cotton plants native to Mexico's Yucatán Peninsula may all look the same — unkempt shrubs with flowers that shift from white to violet as pollinators visit them. But genes that have escaped from genetically modified cotton crops have changed the biology of some of these native plants, altering how they interact with insects.

One type of escaped gene makes wild cotton exude less nectar. With no means to attract defensive ants that protect it from plant eaters, the cotton plant is attacked more. Another escaped gene makes the wild cotton produce excess nectar, enticing a lot of ants that may keep other insects, including pollinators, at bay, researchers report January 21 in *Scientific Reports*.

"It's the first case that really suggests that a whole ecosystem can be disrupted" after transgenes, or introduced genes, enter a wild population, says Norman Ellstrand, an evolutionary biologist at the University of California, Riverside who was not involved with the study.

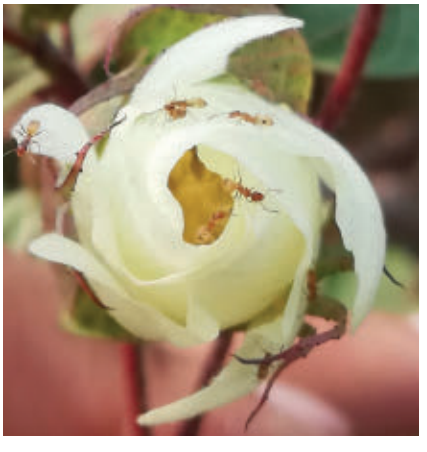
The results challenge a long-held view that when genes from a genetically modified crop escape into the wild, they have only a neutral effect on wild plants or pass on their benefits to weeds, says Alicia Mastretta Yanes, a plant molecular ecologist at the National Commission for the Knowledge and Use of Biodiversity in Mexico City who wasn't involved with the study. The findings show that unexpected outcomes, some of which "were never imagined, or at least were not assumed as possible," do happen sometimes, she says.

Scientists have previously tried to explain what happens after DNA from genetically modified crops ends up in their wild relatives (*SN: 2/6/16, p. 22*). But the majority of these studies have been done under carefully controlled conditions, and very few have tested the consequences, if any, of these gene transfers on natural ecosystems.

The scarce evidence motivated Ana Wegier, a plant geneticist at the National Autonomous University of Mexico in Mexico City, and her students to find out. The cotton we know, *Gossypium hirsutum*, first appeared and diversified between 2 million and 1.5 million years ago in Mexico, and native varieties still sprout across the country. In the last 25 years, vast fields of fluffy, genetically engineered cotton have been planted in northern Mexico.

During that time, Wegier has searched for wild cotton, only to find it in municipal dumps, the middle of a highway or at the edge of cliffs. Wild cotton likes to grow in the most inhospitable locations, where it doesn't have to compete with other species, she says. In 2018, Wegier and her group traveled to the Ría Lagartos biosphere reserve, an isolated coastal area on southeastern Mexico's Yucatán Peninsula. The researchers spent long days observing and sampling cotton plants under the scorching sun as swarms of mosquitoes bit them nonstop.

Back in the lab, the team extracted DNA from 61 collected plants and found that 24 did not have any transgenes. Twenty-one plants had a transgene that confers resistance to the herbicide glyphosate; seven had a transgene that enabled them to produce a toxin that kills destructive insects; and the remaining nine had incorporated both of these escaped genes into their genetic code.



Ants patrol the flower of this wild cotton plant on the Yucatán Peninsula in Mexico, warding off hungry herbivores.

VALERIA VÁZQUEZ-BARRIOS

With the closest fields of genetically engineered cotton almost 2,000 kilometers away, "what surprised me the most," Wegier says, "was how easy it was to find changes where we didn't expect them."

When slathered in a stress-inducing chemical, the plants with glyphosate tolerance produced much less nectar than wild plants without transgenes. Wild cotton secretes the nectar whenever it's eaten in exchange for the bodyguard services of aggressive ant species. These plants were also the ones that looked the most ragged before the samples were taken. With no reward to offer, and thus no ants to protect the cotton from herbivores, these plants suffered the most damage compared with native plants that didn't have the transgene.

Regardless of the chemical treatment, the plants with the insecticide gene exuded nectar all the time, secreting more than the wild plants with no escaped genes and becoming a beacon to the ants. But in the researchers' sample of plants, there weren't as many with the insecticide gene, suggesting that either the ants or the transgene itself were scaring off other insects. That may have interfered with the pollination of cotton flowers, preventing reproduction, Weiger says.

The findings are intriguing, says Hugo Perales, an agroecologist at the Colegio de la Frontera Sur in San Cristóbal de las Casas, Mexico, but he urges caution. The real-world environment of Ría Lagartos forced the researchers to work with a very small number of plants, he says. "There's a suggestion that something is happening, but this suggestion needs to be verified."

To Wegier, the study's implications are clear. With Mexico being the reservoir of cotton's genetic diversity, she argues it would be wise to limit the introduction of more genetically modified varieties. "We know the presence of transgenes is irreversible," she says, "and the [ecological] effects are irreversible." ■

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HUMANS & SOCIETY

Stonehenge may have Welsh roots

Excavations suggest a distant origin for some of the stones

BY BRUCE BOWER

At an ancient site in Wales, researchers suspect they have uncovered the remnants of a stone circle that contained initial building blocks of Stonehenge.

Excavations are in the early stages, but the stone circle was probably dismantled between 5,400 and 5,200 years ago, say archaeologist Mike Parker Pearson of University College London and colleagues. That's a few hundred years or less before work began at Stonehenge. Ancient people at the newly excavated site may have moved about 280 kilometers to southern England, bringing stones that were used in the first phase of building the monument, the investigators propose in the February *Antiquity*.

Stonehenge (shown) was constructed partly from a dismantled stone circle in western Wales that was transported to southern England, a group of researchers argues.

Others, though, caution that more excavation is needed to clinch the case.

The stone circle was found at Waun Mawn, a site in western Wales that's near quarries previously identified as sources of smaller Stonehenge stones known as bluestones. If Parker Pearson's team is right, then population movements out of Wales explain why bluestones at Stonehenge came from far away. Other Stonehenge stones, such as the massive boulders, came from local sources.

Signs of human activity in western Wales largely disappeared about 5,000 to 4,000 years ago. "Maybe most of the people migrated, taking their stones — their ancestral identities — with them," Parker Pearson says. Analyses of chemical elements in cremated human remains at Stonehenge previously indicated that a substantial number of those people had come from western Wales.

Excavations at Waun Mawn in 2017 and 2018 revealed an arc of four former standing stones and six earthen holes from which stones had been removed. Those finds formed part of a circle of 30 to 50 standing stones, the researchers estimate. Dating of sediment and burned

ATOM & COSMOS

A cosmic beast gains some weight

The first black hole ever found is more massive than thought

BY MARIA TEMMING

The first black hole ever discovered still has a few surprises in store.

New observations of the black hole–star pair called Cygnus X-1 indicate that the black hole weighs about 21 times as much as the sun — nearly 1.5 times heavier than past estimates. The updated mass has astronomers rethinking how some black hole–forming stars evolve. For a star-sized, or stellar, black hole that massive to exist in the Milky Way, its parent star must have shed less mass through stellar winds than expected, researchers report online February 18 in *Science*.

Knowing how much mass stars lose through stellar winds over their lifetimes is important for understanding how these stars enrich their surroundings with heavy elements. It's also key to understanding the masses and compositions of those stars when they explode and leave behind black holes.

The updated mass is "a big change to an old favorite," says Tana Joseph, an astronomer at the University of Amsterdam not involved in the work. Stephen Hawking famously bet physicist Kip Thorne that the Cygnus X-1 system, found in 1964, did not include a black hole — and conceded the wager in 1990, when scientists had broadly accepted that Cygnus X-1 had the first known black hole in the universe.

Astronomers got a new look using the Very Long Baseline Array, or VLBA, a network of 10 radio dishes that stretches across the United States, collectively forming a continent-sized radio dish. In 2016, the VLBA tracked bright jets of material spewing out of Cygnus X-1's black hole for six days, covering the time it took for the black hole and its companion star to orbit each other once. Those observations offered a clear view of how the black hole's position in space shifted during the orbit. That, in turn, helped scientists refine the estimated distance to Cygnus X-1.

Cygnus X-1 is now thought to be about 7,200 light-years from Earth, not 6,000 light-years as previously estimated. This implies that the star in Cygnus X-1 is even brighter, and therefore bigger, than astronomers thought. The star weighs about 40.6 suns, the researchers estimate. The black hole must also be more massive to explain its gravitational tug on such a massive star. The black hole weighs about 21.2 suns — much heftier than its previously estimated 14.8 solar masses.

The mass of the black hole is so big that

STEVE BANNER/500PX/GETTY IMAGES

wood provided the site's age estimate.

Several features link Waun Mawn to Stonehenge, the scientists say. First, two adjacent stone holes were arranged so that the stones formed an entryway that, when viewed from the circle's center, faced the midsummer solstice sunrise. Stonehenge has the same alignment.

Second, one bluestone at Stonehenge features a five-sided cross section at its base that matches the shape and dimensions of an unearthed Waun Mawn stone hole. This Stonehenge bluestone potentially came from the Wales site, the researchers say. Third, the complete Waun Mawn stone circle had an estimated diameter of 110 meters, the same as the ditch that encircles Stonehenge.

But there's reason to be skeptical, says archaeologist Timothy Darvill of Bournemouth University in Poole, England. "Whether the discoveries at Waun Mawn are really the remains of a stone circle needs further work." For instance, known stone circles typically have evenly spaced stones; Waun Maun's stones are irregularly spaced. And some earthen sockets at the site may have been created by farmers clearing fields. ■

it challenges astronomers' understanding of the massive stars that collapse to form black holes, says study coauthor and astrophysicist Ilya Mandel of Monash University in Melbourne, Australia.

"Sometimes stars are born with quite high masses — there are observations of stars being born with masses of well over 100 solar masses," Mandel says. But such enormous stars are thought to shed much of their weight through stellar winds before turning into black holes. The bigger the star and the more heavy elements it contains, the stronger its stellar winds. So in heavy element–rich galaxies such as the Milky Way, big stars — no matter the starting mass — are supposed to shrink down to about 15 solar masses before collapsing into black holes.

Cygnus X-1's black hole undermines that idea. "Maybe we're not losing as much mass through stellar winds as we initially thought," Joseph says. ■

C. DAVIS/DAVIS LAB

GENES & CELLS

A parasitic plant is missing many genes

Sapria himalayana is also taking a lot of DNA from its hosts

BY JAKE BUEHLER

For most of their lives, plants in the *Sapria* genus are barely anything — thin threads of parasitic cells winding inside vines in South and Southeast Asian rainforests. The plants become visible only when they reproduce, bursting from their host as a nearly dinner plate–sized flower that smells like rotting flesh.

Now, research on the genetic instruction book of this rare plant reveals the lengths to which it has gone to become a specialized parasite. The findings, published in the March 8 *Current Biology*, suggest that at least one *Sapria* species has lost nearly half of the genes commonly found in related flowering plants and has stolen many others from hosts.

The rewired genetics echo the plant's bizarre biology. *Sapria* and relatives in the family Rafflesiaceae have long ago discarded stems, roots and photosynthetic tissue.

"If you're out in the forest in Borneo and these [plants] aren't producing flowers, you're never even going to know they're there," says Charles Davis, an evolutionary biologist at Harvard University.

When some genetic data showed a close relationship between the parasites and their vine hosts, Davis suspected horizontal gene transfer, where genes move directly from one species to another. But no one had yet deciphered a genome — the full genetic instruction book — for these plants.

So Davis' team analyzed millions of pieces of *Sapria himalayana*'s genome to assemble a cohesive picture, and found an abundance of oddities.

About 44 percent of the genes found in many flowering plants are absent. Yet, *S. himalayana*'s genome has about 55,000 genes, more than that of some nonparasitic plants. The count is inflated by many repeating segments of DNA.

Loss of the chlorophyll pigments needed for photosynthesis is not unheard of in parasitic plants. But *S. himalayana* appears to have scrapped all genetic remnants of chloroplasts, the cellular structures where photosynthesis occurs.

Sapria himalayana, native to South and Southeast Asia, lives inside a host vine before emerging as a speckled flower that can measure 20 centimeters across.

Evolutionary biologist Alex Twyford of the University of Edinburgh cautions that it may be too early to declare all the chloroplast DNA gone. It may be hard to prove the absence, he says, if the chloroplast is "unusual in its structure or abundance" and therefore hard to identify.

More than 1 percent of the plant's nuclear genome, the DNA enclosed in the cell nucleus, comes from genes stolen from other plants, likely current and ancestral hosts, the team found. The "industrial scale" of this gene theft is impressive, says Arjan Banerjee, a biologist at the University of Toronto Mississauga.

Why *S. himalayana* has such a bloated genome, while most parasites streamline their genomes, is unclear, says study coauthor Tim Sackton, an evolutionary biologist also at Harvard. "There's something weird and different going on in this species," he says, adding that many of the DNA fragments the plant is taking from hosts don't appear to encode any genes, and likely don't do anything important. ■

BODY & BRAIN

Mask fit is vital for curbing COVID-19

A snugger face covering reduces exposure by up to 96 percent

BY TINA HESMAN SAEY

By now, most people have gotten the message that wearing a face mask is one way to help stop the spread of COVID-19. But now health officials are taking that message a step further: Don't just wear a mask, wear it well.

Improving the way medical masks fit can protect wearers from about 96 percent of the aerosol particles thought to spread the coronavirus, a study by the U.S. Centers for Disease Control and Prevention finds. That's provided others also wear masks. But even if not, wearing a mask that fits snugly can protect the wearer from up to 83 percent of potentially virus-carrying particles, researchers report February 10 in *Morbidity and Mortality Weekly Report*.

"The bottom line is this: Masks work, and they work best when they have a good fit and are worn correctly," CDC director Rochelle Walensky said February 10 during a White House briefing.

That message is increasingly crucial as more transmissible coronavirus variants, including ones first detected in South Africa and the United Kingdom, spread more widely.

Plenty of studies have demonstrated that masks reduce the amount of spit particles that may spray others when a person breathes, talks, coughs or sneezes. But air and droplets can escape from the tops, sides and bottoms of ill-fitting masks. "Even a small gap can degrade the performance of your mask by 50 percent," says Linsey Marr, an environmental engineer at Virginia Tech in Blacksburg.

Several recent studies have shown that simple measures to improve fit can cut down aerosol emissions.

To test some of those measures, John Brooks, chief medical officer for the CDC's COVID-19 emergency response, and colleagues set up two manikins facing each other six feet apart. Via a tube, one manikin "exhaled" saltwater aerosol particles of a size that could carry the coronavirus. The researchers measured how many saline droplets reached a mouthpiece in the second manikin representing its nose and throat.

Aerosols can spew from gaps where medical masks don't fit the face (top, as demonstrated on a manikin). A mask fitter worn over such a mask can prevent that leakage (bottom).

When the receiver wore an ill-fitting medical mask, the amount of droplets was reduced by 7.5 percent compared with when neither manikin wore a mask. When the source was the one wearing a mask, the receiver's exposure was reduced by 41.3 percent. And when both dummies wore masks, particle exposure was 84.3 percent lower than with no masks.

The team also investigated two ways to make the mask fit better: knotting the ear loops close to the mask and tucking in the ends to eliminate side gaps; and wearing a cotton cloth mask over the medical mask. When the receiver wore a knotted and tucked mask, its exposure was reduced by 64.5 percent compared with when neither manikin wore a mask. When both manikins wore the knotted and tucked masks, exposure dropped by 95.9 percent.

Wearing a cloth mask over the medical mask improved fit even more. When just the receiving manikin wore the double mask, it was protected from 83 percent of particles. And when both manikins doubled up on masks, 96.4 percent of particles were blocked.

Those data show that "it's mask fit that really matters, and there are a bunch of different ways to improve mask fit," says David Rothamer, a mechanical engineer at the University of Wisconsin–Madison College of Engineering.

Rothamer and colleagues recently tested mask fitters or mask braces — rubber or plastic frames that fit over the mask to mold it more closely to the face. A medical mask alone filters about 20 percent of aerosol droplets leaving the mouth. With a mask fitter in place, 90 to 95 percent of droplets were filtered, the team reported online January 4 at medRxiv.org. That report hasn't yet been peer-reviewed.

Piling on masks beyond two probably won't improve filtration and may make it difficult to breathe, says infectious diseases doctor Monica Gandhi of the University of California, San Francisco.

She and Marr proposed the double masking strategy in the Jan. 15 *Med*. Medical mask material is electrostatically charged, which may repel microbes, in addition to filtering particles. The cloth mask helps reduce gaps around the sides and top of the medical mask. Although the CDC study tested the cloth mask over the medical mask, Gandhi says the order may not matter.

There are many simple ways to improve the fit of masks, says Emily Sickbert-Bennett, an epidemiologist at the University of North Carolina Medical Center in Chapel Hill. A pantyhose sleeve over a medical mask improved filtration to about 80 percent, she and colleagues reported December 10 in *JAMA Internal Medicine*. A mask fitter made of rubber bands as well as devices known as ear guards or ear savers also performed well.

Beyond the question of fit, the CDC report illustrates how important it is for everyone to wear masks, Sickbert-Bennett says. "The best form of double masking is when you and the person you're interacting with are both wearing a mask." ■

SCOTT SANDERS

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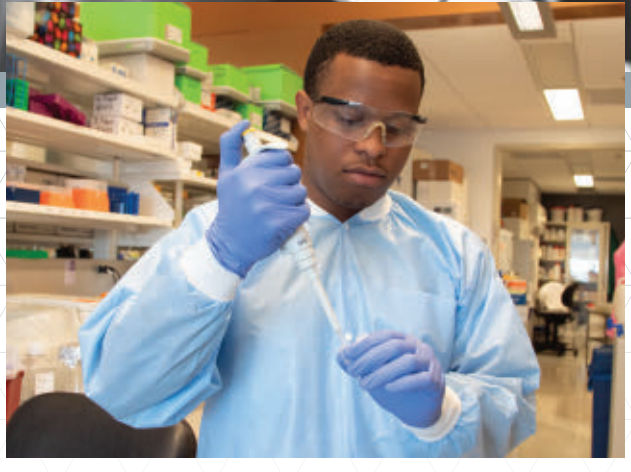

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Our Brains, Our Futures

A fantastical view of neuroscience has roots in recent research advances

By Laura Sanders

A century ago, science's understanding of the brain was primitive, like astronomy before telescopes. Certain brain injuries were known to cause specific problems, like loss of speech or vision, but those findings offered a fuzzy view.

Anatomists had identified nerve cells, or neurons, as key components of the brain and nervous system. But nobody knew how these cells collectively manage the brain's sophisticated control of behavior, memory or emotions. And nobody knew how neurons communicate, or the intricacies of their connections. For that matter, the research field known as neuroscience — the science of the nervous system — did not exist, becoming known as such only in the 1960s.

Over the last 100 years, brain scientists have built their telescopes. Powerful tools for peering inward have revealed cellular constellations. It's likely that over 100 different kinds of brain cells communicate with dozens of distinct chemicals. A single neuron, scientists have discovered, can connect to tens of thousands of other cells.

Yet neuroscience, though no longer in its infancy, is far from mature.

Today, making sense of the brain's vexing complexity is harder than ever. Advanced technologies and expanded computing capacity churn out torrents of information. "We have vastly more data ... than we ever had before, period," says Christof Koch, a neuroscientist at the Allen Institute in Seattle. Yet we still don't have a satisfying explanation of how the brain operates. We may never understand brains in the way we understand rainbows, or black holes, or DNA.

ScienceNews 100

To celebrate our upcoming 100th anniversary, we've launched a series that highlights some of the biggest advances in science over the last century. For more on the story of the human brain, and to see the rest of the series as it appears, visit the Century of Science site at www.sciencenews.org/century

Deeper revelations may come from studying the vast arrays of neural connections that move information from one part of the brain to another. Using the latest brain mapping technologies, scientists have begun drawing detailed maps of those neural highways, compiling a comprehensive atlas of the brain's communication systems, known as the connectome.

Those maps are providing a more realistic picture than early work that emphasized the roles of certain brain areas over the connections among them, says Michael D. Fox, a neuroscientist who directs the Center for Brain Circuit Therapeutics at Brigham and Women's Hospital in Boston.

Scientists now know that the dot on the map is less important than the roads leading in and out.

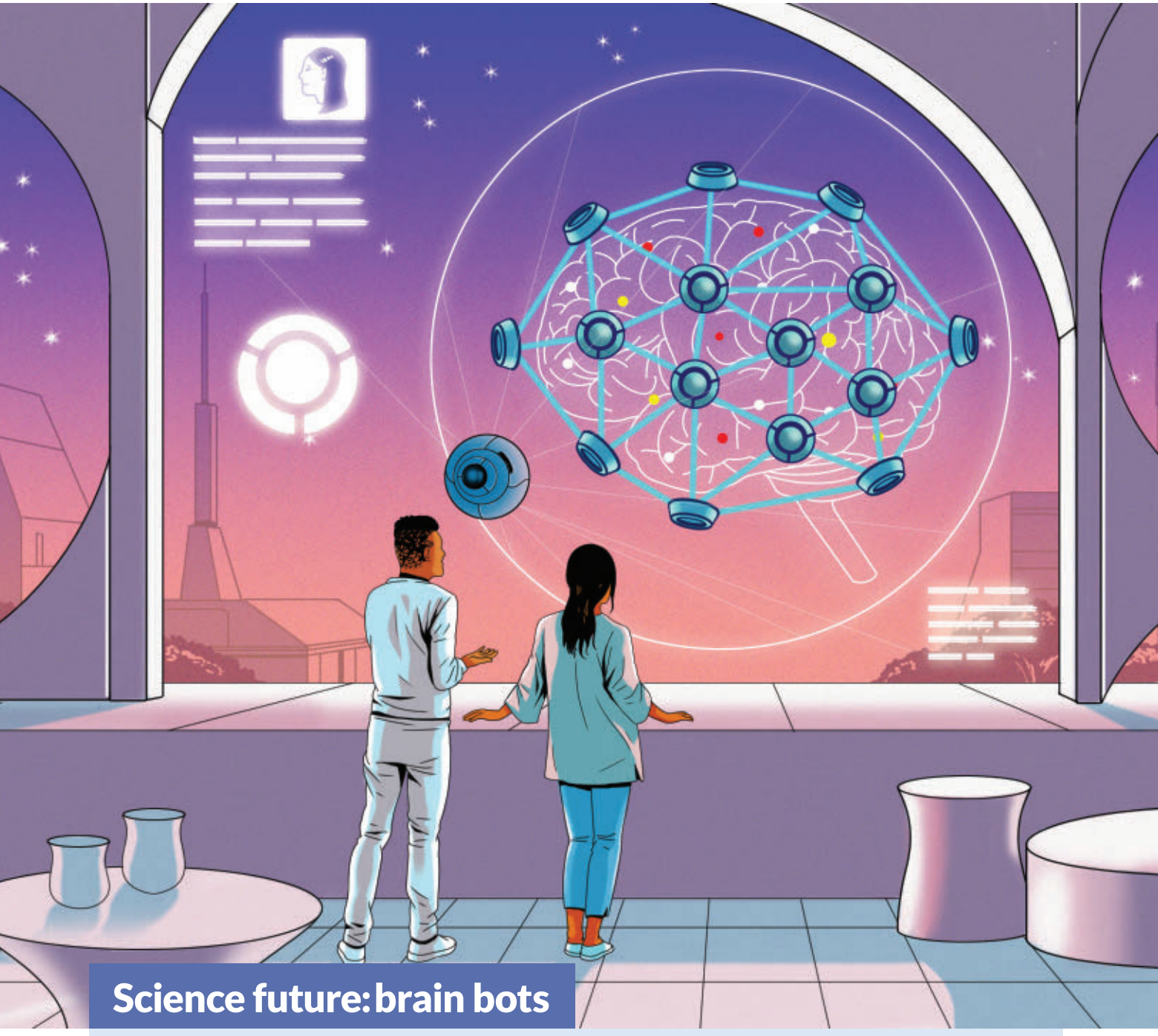
"With the building of the human connectome, this wiring diagram of the human brain, we all of a sudden had the resources and the tools to begin to look at [the brain] differently," Fox says.

Scientists are already starting to use these new brain maps to treat disorders. That's the main goal of Fox's center, dedicated to changing brain circuits in ways that alleviate disorders such as Parkinson's disease, obsessive-compulsive disorder and depression. "Maybe for the first time in history, we've got the tools to map these symptoms onto human brain circuits, and we've got the tools to intervene and modulate these circuits," Fox says.

The goal sounds grandiose, but Fox doesn't think it's a stretch. "My deadline is a decade from now," he says.

Whether it's 10 years from now or 50, by imagining what's ahead, we can remind ourselves of the progress that's already been made, of the neural galaxies that have been discovered and mapped. And we can allow ourselves a moment of wonder at what might come next.

The three fictional vignettes that follow illustrate some of those future possibilities. No doubt they will be wrong in the details, but each is rooted in research that's under way today, as described in the "reality checks" that follow each imagined scenario.



Science future: brain bots

Sarah had made up her mind. After five years, she was going to get her neural net removed.

The millions of nanobots in her brain had given her life back to her, by helping her mind to work again. They had done their job. It was time to get them out.

After Sarah's baby was born on the summer solstice, things got dark. The following months had tipped Sarah into a postpartum depression that kept her from enjoying her gorgeous, perfect little girl.

Unable to feel much of anything, Sarah barely moved through those early days. She rarely looked at the baby. She forgot to eat. She would sit in a dark room for hours, air conditioner on full blast, staring at nothing. Those endless days stretched until an unseasonably hot September morning. Her mother watched the baby while Sarah's husband drove

GLENN HARVEY

her to the Institute for Neuroprosthetics, a low-slung brick building in the suburbs of Nashville.

Inside, Sarah barely listened as the clinic coordinator described the technology again. An injection would deliver the nanobots to her blood. Then a tech would guide the bots, using a magnet, from her arm toward her head. A fast, strong pulse of ultrasound would open the blood-brain barrier temporarily, allowing an army of minuscule particles to slip in.

Powered by the molecular motion inherent in the brain, the nanobots would spread out to form a web of microscopic electrodes. That neural network could pinpoint where Sarah's brain circuitry was misfiring and repair it with precise but persuasive electrical nudges.

Over the following weeks, Sarah's nanobots learned the neural rhythms of her brain as she moved through her life with debilitating depression. With powerful computational help — and regular tinkering by the clinic technologist — the system soon learned to spot the earliest neural rumblings of a deteriorating mood. Once those warning signs were clear, Sarah's web of nanobots could end budding episodes before they could take her down.

Soon after the injection, Sarah's laugh started to reappear, though sometimes at the wrong times. She recalled the day she and her husband took the baby to a family birthday party. In the middle of a story about her uncle's dementia treatment, Sarah's squawks of laughter silenced the room.

Those closest to her understood, but most of her family and friends didn't know about the millions of bots working to shore up her brain.

After a few months and some adjustments, Sarah's emotions evened out. The numb, cold depression was gone. Gone too were the inappropriate bursts of laughter, flashes of white rage and insatiable appetites. She was able to settle in with her new family, and feel — really feel — the joy of it all.

But was this joy hers alone? Maybe it belonged to the army of tiny, ever-vigilant helpers, reworking and evening out her brain. Without her neural net, she might have been teary watching her daughter, still her baby, walk into her kindergarten classroom on the first day. Instead, Sarah waved, turned and went to work, feeling only slightly wistful, nothing more intense than that.

The science supporting the success of neural nets was staggering. They could efficiently fix huge problems: addiction, dementia, eating disorders and more. But the science couldn't answer bigger questions of identity and control — what it means to be a person.

That search for herself is what drove Sarah back to the clinic, five years after she welcomed the nanobots in.

Her technologist went over the simple extraction procedure: a quick ultrasound pulse to loosen the blood-brain barrier again, a strong magnet over the inside of Sarah's elbow and a blood draw. He looked at her. "You ready?"

She took a deep breath. "Yes."

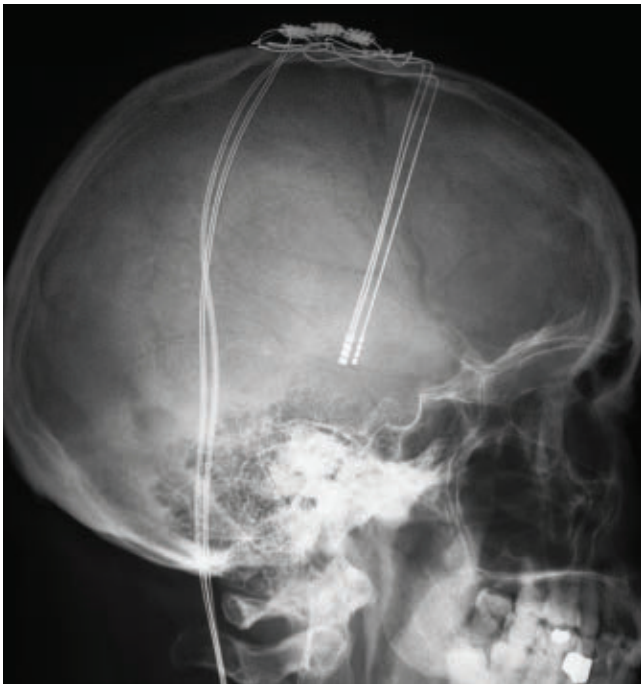
Reality check: brain bots

In this story, Sarah received a treatment that doesn't exist in the real world. But the idea that scientists will be able to change certain brain networks — and improve health — is not fiction. It's happening.

Already, a technique known as deep brain stimulation, or DBS, uses electrodes surgically implanted in people's brains to tweak the behavior of brain cells. Such electrode implants are helping reduce Parkinson's tremors, epileptic seizures and uncontrollable movements caused by Tourette's syndrome. Mood disorders like Sarah's have been targeted too.

The central idea of DBS — that the brain can be fixed by stimulating it — is not new. In the 1930s, psychiatrists discovered that a massive wallop of seizure-inducing electricity could sometimes relieve psychiatric symptoms. In the 1940s and 1950s, researchers studied whether more constrained electrical stimulation could help with disorders such as depression.

In 1948, for instance, neurosurgeon J. Lawrence Pool of Columbia University's Neurological Institute of New York implanted electrodes to stimulate the brain of a woman with severe Parkinson's who had become depressed and lost weight. Soon, she began to "eat well, put on weight and react in a more cheerful manner," Pool reported in 1954.



Electrodes penetrate deep into the brain of a 58-year-old person to treat Parkinson's disease. Deep brain stimulation is being improved and tested in movement disorders, obsessive-compulsive disorder and depression.

ZEPHYR/SCIENCE SOURCE

The experiment ended three years later when one of the wires broke. "It is the writer's conviction that focal controlled stimulation of the human brain is a new technique in psychosurgery that is here to stay," Pool wrote.

Compared with those early days, today's scientists understand a lot more about how to selectively influence brain activity. But before a treatment such as Sarah's is possible, two major challenges must be addressed: Doctors need better tools — nimble and powerful systems that are durable enough to work consistently inside the brain for years — and they need to know where in the brain to target the treatment. That location differs among disorders, and even among people.

These are big problems, but the various pieces needed for this sort of precision healing are beginning to coalesce.

The specs of the technology that will be capable of listening to brain activity and intervening as needed is anyone's guess. Yet those nanobots that snuck into Sarah's brain from her blood do have roots in current research. For example, Caltech's Mikhail Shapiro and colleagues are working toward nanoscale robots that roam the body and act as doctors (*SN: 10/10/20 & 10/24/20, p. 27*).

Other kinds of sensors are growing up, fast. In the last 20 years, electrodes have improved by an astonishing amount, becoming smaller, more flexible and less likely to scar the brain, says biomedical engineer Cynthia Chestek. When she began working on electrode development in the early 2000s, there were still insolvable problems, she says, including the scars that big, stiff electrodes can leave, and the energy they require to operate. "We didn't know if anybody was ever going to deal with them."

But those problems have largely been overcome, says Chestek, whose lab team at the University of Michigan in Ann Arbor develops carbon fiber electrodes. Imagine the future, Chestek says. "You could have thousands of electrodes safely interfacing with neurons. At that point, it becomes really standard medical practice."

Neural dust — minuscule electrodes powered by external ultrasounds — already can pick up nerve and muscle activity in rats. Neuropixels can record electrical activity from over 10,000 sites in mice's brains. And mesh electrodes, called neural lace, have been injected into the brains of mice.

Once inside, these nets integrate into the tissue and record brain activity from many cells. So far, these mesh electrodes have captured neural activity over months as the mice have scurried around.

Other systems under development can be controlled with magnets, light or ultrasound. There are still problems to solve, Chestek says, but none are insurmountable. "We just need to figure out the last set of practical tricks," she says.

Once scientists know how to reliably change brain activity, they need to know where to make the change. Precision targeting is complicated by the fact that ultimately, every part of the brain is connected to every other part, in a very Kevin Bacon way.

IMEC

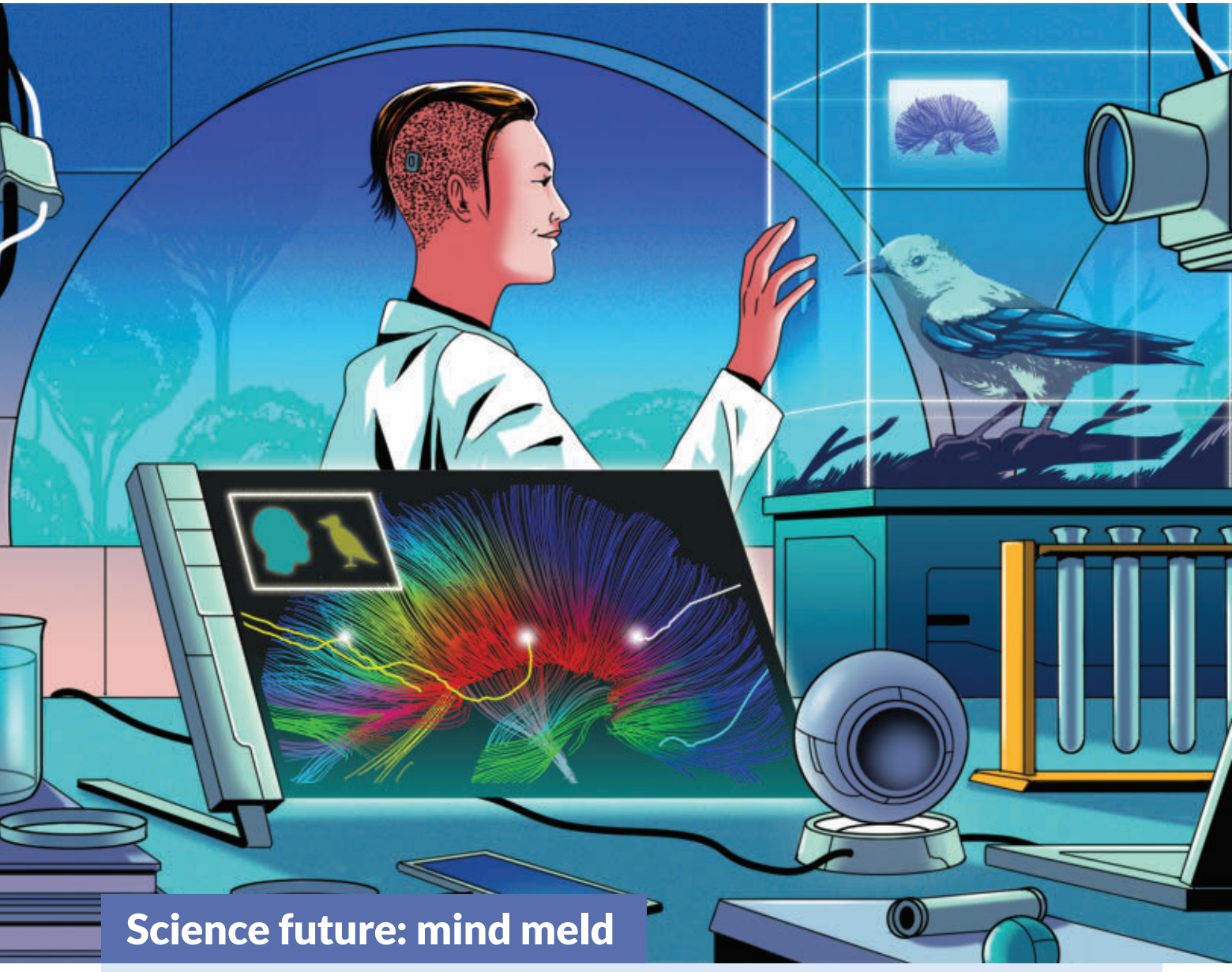
Arrays of electrodes are getting smaller and more reliable, collecting an onslaught of data about brains at work. Shown is Neuropixels, an array created by the company Imec, that contains nearly 1,000 electrodes.

Advances in tractography — the study of the physical connections among groups of nerve cells — are pointing to which parts of these neural highways could be targeted to deal with certain problems.

Other studies of people with implanted electrodes reveal brain networks in action. When certain electrodes were stimulated, people experienced immediate and obvious changes in their moods (*SN: 2/16/19, p. 22*). Those electrodes were near the neural tracts that converge in a brain region just behind and above the eyes called the lateral orbitofrontal cortex.

In the future, we might all have our personalized brain wiring diagrams mapped, Fox says. And perhaps for any symptom — anxiety, food craving or addiction — doctors could find the brain circuit responsible. "Now we've got our target," he says. "We can either hold the neuromodulation tool outside your scalp, or implant a tool inside your head, and we're going to fix that circuit."

The hurdles to building a nimble, powerful and precise system similar to the one that helped Sarah are high. But past successes suggest that innovative, aggressive research will find ways around current barriers. For people with mood disorders, addiction, dementia or any other ailment rooted in the brain, those advances can't come soon enough.



Science future: mind meld

Sofia couldn't sleep. Tomorrow was the big day. As the project manager for the Nobel Committee for Physiology or Medicine, she had overseen years of prize announcements, but never one like this.

At 11:30 a.m. Central European Summer Time tomorrow, the prize would be given to a bird named Harry, a 16-year-old Clark's nutcracker. Sofia smiled in the dark as she thought about how the news would land.

Harry was to be recognized for benefiting humankind "in his role as a pioneering memory collective that enhances human minds." Harry would share the prize (and the money) with his two human trainers.

Tomorrow morning, the world would be buzzing, Sofia knew. But as with every Nobel Prize, the story began long before the announcement. Even in the 20th century, scientists had been dreaming of, and tinkering with, merging different kinds of minds.

As the technology got more precise and less invasive, human-to-human links grew seamless, inspired by ancient and intriguing examples of conjoined twins with shared awareness. External headsets could send and receive signals between brains, such as "silent speech" and sights and sounds.

Next, scientists began looking to other species' brains for

GLENN HARVEY

different types of skills that might boost our human abilities. Other animals have different ways of seeing, feeling, experiencing and remembering the world. That's where Harry came in.

Crows, ravens and other corvids have prodigious memories. That's especially true for Clark's nutcrackers. These gray and black birds can remember the locations of an estimated 10,000 seed stashes at any given time. These powerful memory abilities soon caught the eye of scientists eager to augment human memory.

The scientists weren't talking about remembering where the car is parked in the airport lot. They set their sights higher. Done right, these enhancements could allow a person to build stunningly complete internal maps of their world, remembering every place they had ever been. And it turned out that these memory feats didn't just stop at physical locations. Strengthening one type of memory led to improvements in other kinds of memories too. The systems grew stronger all around.

Harry wasn't the first bird to link up with humans, but he has been one of the best. As a young bird, Harry underwent several years of intense training (aided by his favorite treat, whitebark pine seeds). Using a sophisticated implanted brain chip, he learned to merge his neural signals with those of a person who was having memory trouble or needed a temporary boost. The connection usually lasted for a few hours a day, but its effects endured. Noticeable improvements in people's memories held fast for months after a session with Harry. The people who tried it called the change "breathtaking." The bird had made history.

By showing this sort of human-animal mind meld was possible, and beneficial, Harry and his trainers had helped create an entirely new field, one worthy of Nobel recognition, Sofia thought.

Some scientists are now building on what Harry's brain could do during these mingling sessions. Others are expanding to different animal abilities: allowing people to "see" in the dark like echolocating bats, or "taste" with their arms like octopuses. Imagine doctors being able to smell diseases, an olfactory skill borrowed from dogs. News outlets were already starting to run interviews with people who had augmented animal awareness.

Still wide awake, Sofia's mind ran back through the meetings she had held with her communications team over the last week. Tomorrow's announcement would bring amusement and delight. But she also expected to hear strong objections, from religious groups, animal rights activists and even some ethicists concerned about species blurring. The team was prepared for protests, lots of them.

In the middle of the night, these worries seemed a smidge more substantial to Sofia. Then she thought of Harry flitting around, hiding seeds, and the threat faded away. Sofia marveled at how far the science had come since she was a girl, and how far it was bound to go. Fully exhausted, she rolled over, ready to sleep, ready for tomorrow. She smiled again as she thought about what she'd tell people, if the chance arose: For better or worse, resistance is futile.

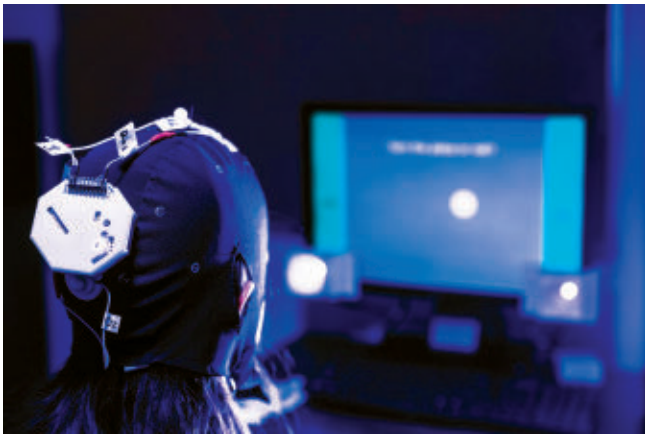
Reality check: mind meld

Accepting that a bird could win a Nobel Prize demands a pretty long flight of fancy. But scientists have already directly linked together multiple brains.

Today, the technology that makes such connections possible is just getting off the ground. We are in the "Kitty Hawk" days of brain interface technologies, says computational neuroscientist Rajesh Rao of the University of Washington in Seattle, who is working on brain-based communication systems. In the future, these systems will inevitably fly higher.

Such technology might even take people beyond the confines of their bodies, creating a sort of extended cognition, possibly enabling new abilities, Rao says. "This direct connection between brains — maybe that's another way we can make a leap in our human evolution."

Rao helped organize a three-way direct brain chat, in which three people sent and received messages using only their minds while playing a game similar to Tetris. Signals from the thoughts of two players' brains moved over the internet and into the back of the receiver's brain via a burst of magnetic stimulation designed to mimic information coming from the eyes.



MARK STONE/UNIV. OF WASHINGTON

An EEG cap measures brain signals of a "sender" (shown) as she and two other people play a video game with their brains. Those signals form instructions that are sent directly to the brain of another player who can't see the board but must decide what to do based on the instructions.

Senders could transmit signals that told the receiver to rotate a piece, for instance, before dropping it down. Those results, published in 2019 in *Scientific Reports*, represent the first time multiple people have communicated directly with their brains.

Other projects have looped in animals, though no birds yet. In 2019, people took control of six awake rats' brains, guiding the animals' movements through mazes via thought. A well-trained rat cyborg could reach turning accuracy of nearly 100 percent, the researchers reported.

But those rats took commands from a person; they did not send information back. Continuous back-and-forth exchanges are a prerequisite for an accomplishment like Harry's.

These types of experiments are happening too. A recent study linked three monkeys' brains, allowing their minds to collectively move an avatar arm on a 3-D screen. Each monkey was in charge of moving in two of three dimensions; left or right, up or down, and near or far. Those overlapping yet distinct jobs caused the networked monkeys to flounder initially. But soon enough, their neural cooperation became seamless as they learned to move the avatar arm to be rewarded with a sip of juice.

With technological improvements, the variety of signals that can move between brains will increase. And with that, these brain collectives might be able to accomplish even more. "One brain can do only so much, but if you bring many brains together, directly connected in a network, it's possible that they could create inventions that no single mind could think of by itself," Rao says.

Groups of brains might be extra good at certain jobs. A collective of surgeons, for instance, could pool their expertise for a particularly difficult operation. A collective of fast-thinking pilots could drive a drone over hostile territory. A collective of intelligence experts could sift through murky espionage material.

Maybe one day, information from an animal's brain might augment human brains — although it's unlikely that the neural signals from a well-trained Clark's nutcracker will be the top choice for a memory aid. Artificial intelligence, or even human intelligence, might make better memory partners. Whatever the source, these external "nodes" could ultimately expand and change a human brain's connectome.

Still, connecting brains directly is fraught with ethical questions. One aspect, the idea of an "extended mind," poses particularly wild conundrums, says bioethicist Elisabeth Hildt of the Illinois Institute of Technology in Chicago.

"Part of me is connected and extended to this other human being," she says. "Is this me? Is this someone else? Am I doing this myself?" she asks.

Some scientists think it's too early to contemplate what it might feel like to have our minds dispersed across multiple brains (*SN: 2/13/21, p. 24*). Others disagree. "It may be too late if we wait until we understand the brain to study the ethics of brain interfacing," Rao says. "The technology is already racing ahead."

So feel free to mull over how it would feel to connect minds with a bird. If you were the human who could link to the mind of Harry the Clark's nutcracker, for instance, perhaps you might start to dream of flying.

GLENN HARVEY

Science future: thoughts for sale

Javier had just been fired. "They're done with me," he told his coworker Marcus. "They're done with the whole Signal program."

Marcus shook his head. "I'm sorry, man."

Javier went on: "It gets worse; they're moving all of Signal's data into the information market."

The two were in the transportation business. Javier was the director of neural systems engagement for Zou, an on-demand ride hailing and courier system in Los Angeles. After the self-driving industry imploded because of too many accidents, Zou drove into L.A. with a promise of safety — so the company needed to make sure its drivers were the best.

That's where Javier and his team came in. The ambitious idea of the Signal program was to incentivize drivers with cash, using their brain data, gathered by gray headsets.

Drivers with alert and focused brains earned automatic bonuses; a green power bar on-screen in the car showed minute-to-minute earnings. Drivers whose brains appeared sluggish or aggressive didn't earn extra. Instead, they were warned. If the problem continued, they were fired.

This carrot-and-stick system, developed by Javier and his team, worked beautifully at first. But a few months in, accidents started creeping back up.

The problem, it turned out, was the brain itself: It changes. Human brains learn, find creative solutions, remake themselves.

Incentivized to maintain a certain type of brain activity, drivers' brains quickly learned to produce those signals — even if they didn't correspond to better driving. Neural work-arounds sparked a race that Javier ultimately lost.

That failure was made worse by Zou's latest plans. What had started as a driving experiment had morphed into an irresistible way for the company to make money. The plan was to gather and sell valuable data — information on how the drivers' brains responded to a certain style of music, how excited drivers got when they saw a digital billboard for a vacation resort and how they reacted to a politician's promises.

Zou was going to require employees to wear the headsets when they weren't driving. The caps would collect data while the drivers ate, while they grocery shopped and while they talked with their kids, slurping up personal neural details and selling them to the highest bidders.

Of course, the employees could refuse. They could decide to take off the caps and quit. "But what kind of choice is that?" Javier asked. "Most of these drivers would open up their skulls for a paycheck."

Marcus shook his head, and then asked, "How much extra are they going to pay?"

"Who knows," Javier said. "Maybe nothing. Maybe they'll just slip the data consent line into the standard contract."

The two men looked at each other and shook their heads in unison. There wasn't much left to say.

Reality check: thoughts for sale

Javier's fictional program, Signal, was built with information gleaned externally from drivers' brains. Today's technology isn't there yet. But it's tiptoeing closer.

Some companies already sell brain monitoring systems made of electrodes that measure external brain waves with a method called electroencephalography. For now, these headsets are sold as wellness devices. For a few hundred dollars, you can own a headset that promises to fine-tune your meditation practice, help you make better decisions or even level up your golf game. EEG caps can measure alertness already; some controversial experiments have monitored schoolchildren as they listened to their teacher.

The claims by these companies are big, and they haven't been proven to deliver. "It is unclear whether consumer EEG devices can reveal much of anything," ethicist Anna Wexler of the University of Pennsylvania argued in a commentary in *Nature Biotechnology* in 2019. Still, improvements in these devices, and the algorithms that decode the signals they detect, may someday enable more sophisticated information to be reliably pulled from the brain.

Other types of technology, such as functional MRI scans, can pull more detailed information from the brain.

Complex visual scenes, including clips of movies that people were watching, can be extracted from brain scans. Psychologist Jack Gallant and colleagues at the University of California, Berkeley built captivating visual scenes using data from people's brains as they lay in an fMRI scanner. A big red bird swooped across the screen, elephants marched in a row and Steve Martin walked across the screen, all impressionistic versions of images pulled from people's brain activity.

That work, published in 2011, foreshadowed ever more complex brain-reading tricks. More recently, researchers used fMRI signals to re-create faces that people were seeing.

Visual scenes are one thing; will our more nebulous thoughts, beliefs and memories ever be accessible? It's not impossible. Take a study from Japan, published in 2013. Scientists identified the contents of three sleeping people's dreams, using an fMRI machine. But re-creating those dreams required hours of someone telling a scientist about other dreams first. To get the data they wanted, scientists first needed to be invited into the dreamers' minds, in a way. Those three people were each awakened over 200 times early in the experiments and asked to describe what they had been dreaming about.

More portable and more reliable ways to eavesdrop on the brain from the outside are moving forward fast, a swiftness that has prompted some ethicists, scientists and futurists to call for special protections of neural data. Debates over who can access our brain activity, and for what purposes, will only grow more intense as the technology improves. ■

Explore more

- Cara M. Altimus *et al*. "The next 50 years of neuroscience." *Journal of Neuroscience*. January 2020.

Building an Inclusive Genome

How to make DNA data work better for everybody

By Tina Hesman Saey

It's been two decades since the Human Genome Project first unveiled a rough draft of our genetic instruction book. The promise of that medical moon shot was that doctors would soon be able to look at an individual's DNA and prescribe the right medicines for that person's illness or even prevent certain diseases.

That promise, known as precision medicine, has yet to be fulfilled in any widespread way. True, researchers are getting clues about some genetic variants linked to certain conditions and some that affect how drugs work in the body. But many of those advances have benefited just one group: people whose ancestral roots stem from Europe. In other words, white people.

Instead of a truly human genome that represents everyone, "what we have is essentially a European genome," says Constance Hilliard, an evolutionary historian at the University of North Texas in Denton. "That data doesn't work for anybody apart from people of European ancestry."

She's talking about more than the Human Genome Project's reference genome. That database is just one of many that researchers are using to develop precision medicine strategies. Often those genetic databases draw on data mainly from white participants. But race isn't the issue. The problem is that collectively, those data add up to a catalog of genetic variants that don't represent the full range of human genetic diversity.

When people of African, Asian, Native American or Pacific Island ancestry get a DNA test to determine if they inherited a variant that may cause cancer or if a particular drug will work for them, they're often left with more questions than answers. The results often reveal "variants of uncertain significance," leaving doctors with too little useful information. This happens less often for people of European descent. That disparity could change if genetics included a more diverse group of participants, researchers agree (*SN: 9/17/16, p. 8*).

One solution is to make customized reference genomes for populations whose members die from cancer or heart disease at higher rates than other groups, for example, or who face other worse health outcomes, Hilliard suggests.

And the more specific the better. For instance, African Americans who descended from enslaved people have geographic and ecological origins as well as evolutionary and social histories distinct from those of recent African immigrants to the United States. Those histories have left stamps in the DNA that can make a difference in people's health today. The same goes for Indigenous people from various parts of the

DELPHINE LEE

world and Latino people from Mexico versus the Caribbean or Central or South America.

Researchers have made efforts to boost diversity among participants in genetic studies, but there is still a long way to go. How to involve more people of diverse backgrounds — which goes beyond race and ethnicity to include geographic, social and economic diversity — in genetic research is fraught with thorny ethical questions.

To bring the public into the conversation, *Science News* posed some core questions to readers who watched a short video of Hilliard explaining her views.

Again and again, respondents to our unscientific survey said that genetic research is important for improving medical care. But our mostly white respondents had mixed feelings about whether the solution is customized projects such as Hilliard proposes or a more generalized effort to add variants to the existing human reference genome. Many people were concerned that pointing out genetic differences may reinforce mistaken concepts of racial inferiority and superiority, and lead to more discrimination.

Why is genetics so white?

Some of our readers asked how genetic research got to this state in the first place. Why is genetic research so white and what do we do about it?

Let's start with the project that makes precision medicine even a possibility: the Human Genome Project, which produced the human reference genome, a sort of master blueprint of the genetic makeup of humans. The reference genome was built initially from the DNA of people who answered an ad in the *Buffalo News* in 1997.

Although many people think the reference genome is mostly white, it's not, says Valerie Schneider, a staff scientist at the U.S. National Library of Medicine and a member of the Genome Reference Consortium, the group charged with maintaining the reference genome. The database is a mishmash of more than 60 people's DNA.

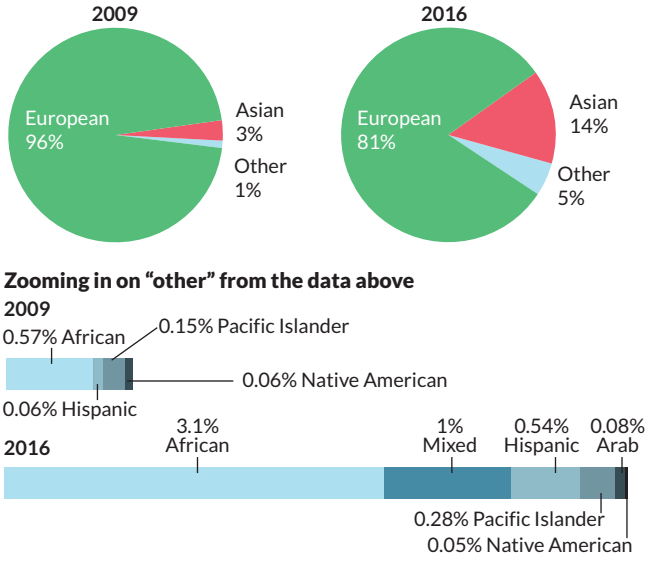
An African American man, dubbed RP11, contributed 70 percent of the DNA in the reference genome. About half of his DNA was inherited from European ancestors, and half from ancestors from sub-Saharan Africa. Another 10 people, including at least one East Asian person and seven of European descent, together contributed about 23 percent of the DNA. And more than 50 people's DNA is represented in the remaining 7 percent of the reference, Schneider says. Information about the racial and ethnic backgrounds of most of the contributors is unknown, she says.

All humans have basically the same DNA. Any two people are 99.9 percent genetically identical. That's why having a reference genome makes sense. But the 0.1 percent difference between individuals — all the spelling variations, typos, insertions and deletions sprinkled throughout the text of the human instruction book — contributes to differences in health and disease.

Much of what is known about how that 0.1 percent genetic difference affects health comes from a type of research called genome-wide association studies, or GWAS. In such studies, scientists compare DNA from people with a particular disease with DNA from those who don't have the disease. The aim is to uncover common genetic variants that might explain why one person is susceptible to that illness while another isn't.

In 2018, people of European ancestry made up more than 78 percent of GWAS participants, researchers reported in *Cell*

Ancestry of individuals in genome-wide association studies



Change is slow Much of the genetic databases that are used to develop precision medicine contain DNA mainly from people of European ancestry. A comparison of 2009 with 2016 shows a slight improvement. By 2019, European ancestry had dropped to 78.4 percent of the DNA.

SOURCES: A. POPEJOY & S. FULLERTON/*NATURE* 2016; G. SIRUGO *ET AL*/*CELL* 2019

in 2019. That's an improvement from 2009, when 96 percent of participants had European ancestors, researchers reported in *Nature*.

Most of the research funded by the major supporter of U.S. biomedical research, the National Institutes of Health, is done by scientists who identify as white, says Sam Oh, an epidemiologist at the University of California, San Francisco. Black and Hispanic researchers collectively receive about 6 percent of research project grants, according to NIH data.

"Generally, the participants who are easier to recruit are people who look like the scientists themselves — people who share similar language, similar culture. It's easier to establish a rapport and you may already have inroads into communities you're trying to recruit," Oh says.

When origins matter

Hilliard's hypothesis is that precision medicine, which tailors treatments based on a person's genetic data, lifestyle, environment and physiology, is more likely to succeed when researchers consider the histories of groups that have worse health outcomes. For instance, Black Americans descended from enslaved people have higher rates of kidney disease and high blood pressure, and higher death rates from certain cancers than other U.S. racial and ethnic groups.

In her work as an evolutionary historian studying the people and cultures of West Africa, Hilliard may have uncovered one reason that African Americans descended from enslaved people die from certain types of breast and prostate cancers at higher rates than white people, but have lower rates of the brittle-bone disease osteoporosis. African Americans have a variant of a gene called *TRPV6* that helps their cells take up calcium. Overactive *TRPV6* is also a hallmark of those breast and prostate cancers that disproportionately kill Black people in the United States.

The variant can be traced back to the ancestors of some African Americans: Niger-Congo–speaking West Africans. In that part of West Africa, the tsetse fly kills cattle, making dairy farming unsustainable. Those ancestral people typically consumed a scant 200 to 400 milligrams of calcium per day. The calcium-absorbing version of *TRPV6* helped the body meet its calcium needs, Hilliard hypothesizes. Today, descendents of some of those people still carry the more absorbent version of the gene, but consume more than 800 milligrams of calcium each day.

Assuming that African American women have the same dietary need for calcium as women of European descent may lead doctors to recommend higher calcium intake, which may inadvertently encourage growth of breast and prostate cancers, Hilliard reported in the *Journal of Cancer Research & Therapy* in 2018.

"Nobody is connecting the dots," Hilliard says, because most research has focused on the European version of *TRPV6*.

One size doesn't fit all

Some doctors and researchers advocate for racialized medicine in which race is used as proxy for a patient's genetic makeup, and treatments are tailored accordingly. But racialized medicine can backfire. Take the blood thinner clopidogrel, sold under the brand name Plavix. It is prescribed to people at risk of heart attack or stroke. An enzyme called CYP2C19 converts the drug to its active form in the liver.

Some versions of the enzyme don't convert the drug to its active form very well, if at all. "If you have the enzyme gene variant that will not convert [the drug], you're essentially taking a placebo, and you're paying 10 times more for something that will not do what something else — aspirin — will do," Oh says.

The inactive versions are more common among Asians and Pacific Islanders than among people of African or European ancestry. But just saying that the drug won't work for someone who ticked the Pacific Islander box on a medical history form is too simplistic. About 60 to 70 percent of people from the Melanesian island nation of Vanuatu carry the inactive forms. But only about 4 percent of fellow Pacific Islanders from Fiji and the Polynesian islands of Samoa, Tonga and the Cook Islands, and 8 percent of New Zealand's Maori people have the inactive forms.

Assuming that someone has a poorly performing enzyme based on their ethnicity is unhelpful, according to Nuala Helsby of the University of Auckland in New Zealand. These examples "reiterate the importance of assessing the individual patient rather than relying on inappropriate ethnicity-based assumptions for drug dosing decisions," she wrote in the *British Journal of Clinical Pharmacology* in 2016.

A far better approach than either assuming that ethnicity

T. TIBBITTS

indicates genetic makeup or that everyone is like Europeans is to analyze a person's DNA and have a precise reference genome to compare it against, Hilliard says. Deciding which genomes to create should be based on known health disparities.

"We have to stop talking about race, and we have to stop talking about color blindness." Instead, researchers need to consider the very particular circumstances and environments that a person's ancestors adapted to, Hilliard stresses.

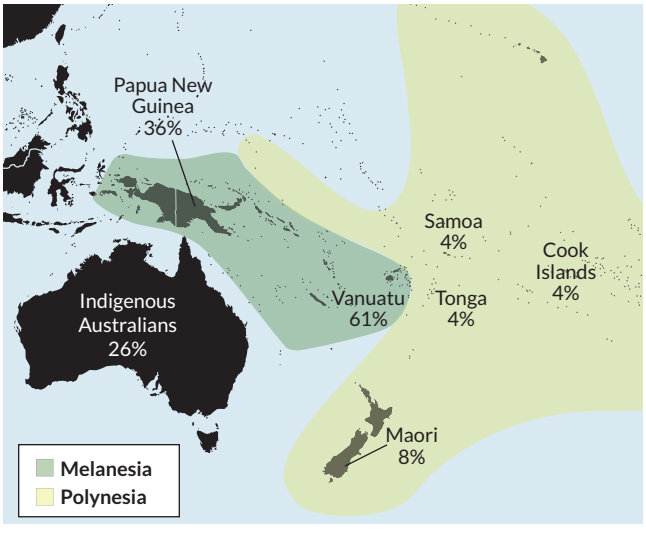
What is diversity in genetics?

Recruiting people from all over the world to participate in genetic research might seem like the way to increase diversity, but that's a fallacy, Hilliard says. If you really want genetic diversity, look to Africa, she says.

Humans originated in Africa, and the continent is home to the most genetically diverse people in the world. Ancestors of Europeans, Asians, Native Americans and Pacific Islanders carry only part of that diversity, so sequencing genomes from geographically dispersed people won't capture the full range of variants. But sequencing genomes of 3 million people in Africa could accomplish that task, medical geneticist Ambroise Wonkam of the University of Cape Town in South Africa proposed February 10 in *Nature* (*SN Online: 2/22/21*).

Wonkam is a leader in H3Africa, or Human Heredity and Health in Africa. That project has cataloged genetic diversity in sub-Saharan Africa by deciphering the genomes of 426 people representing 50 groups on the continent. The team found more than 3 million genetic variants that had never been seen before, the researchers reported October 28 in *Nature*. "What we found is that populations that are not well represented in current databases are where we got the most bang for the buck; you see so much more variation there," says Neil Hanchard, a geneticist and physician at Baylor College of Medicine in Houston.

The chance of having an inactive *CYP2C19* gene varies in the Pacific



Pacific variability The percentage of people who carry ineffective versions of *CYP2C19*, a gene that helps convert a blood thinner to its active form, varies from island to island in the Pacific. Knowing which version a patient has would help doctors choose the best treatment.
SOURCE: N. HELSBY/*BR. J. CLIN. PHARMACOL.* 2016

FROM TOP: DELPHINE LEE; T. TIBBITTS

What's more, groups living side by side can be genetically distinct. For instance, the Berom of Nigeria, a large ethnic population of about 2 million people, has a genetic profile more similar to East African groups than to neighboring West African groups. In many genetic studies, scientists use another large Nigerian group, the Yoruba, "as the go-to for Africa. But that's probably not representative of Nigeria, let alone Africa," Hanchard says.

That's why Hilliard argues for separate reference genomes or similar tools for groups with health problems that may be linked to their genetic and localized geographic ancestry. For West Africa, for example, this might mean different reference datasets for groups from the coast and those from more inland regions, the birthplace of many African Americans' ancestors.

Some countries have begun building specialized reference genomes. China compiled a reference of the world's largest ethnic group, Han Chinese. A recent analysis indicates that Han Chinese people can be divided into six subgroups hailing from different parts of the country. China's genome project is also compiling data on nine ethnic minorities within its borders. Denmark, Japan and South Korea also are creating country-specific reference genomes and cataloging genetic variants that might contribute to health problems that their populations face. Whether this approach will improve medical care remains to be seen.

People often have the notion that human groups exist as discrete, isolated populations, says Alice Popejoy, a public health geneticist and computational biologist at Stanford University. "But we really have, as a human species, been moving around and mixing and mingling for hundreds of thousands of years," she says. "It gets very complicated when you start talking about different reference genomes for different groups." There are no easy dividing lines. Even if separate reference genomes were built, it's not clear how a doctor would decide which reference is appropriate for an individual patient.

Discrimination worries

One big drawback to Hilliard's proposal may be social rather than scientific, according to some *Science News* readers.

Many respondents to our survey expressed concern that even well-intentioned scientists might do research that ultimately increases bias and discrimination toward certain groups. As one reader put it, "The idea of diversity is being stretched into an arena where racial differences will be emphasized and commonalities minimized. This is truly the entry to a racist philosophy."

Another reader commented, "The fear is that any differences that are found would be exploited by those who want to denigrate others." Another added, "The idea that there are large genetic differences between populations is a can of worms, isn't it?"

Indeed, the Chinese government has come under fire for using DNA to identify members of the Uighur Muslim ethnic group, singling them out for surveillance and sending some to "reeducation camps."

People need a better understanding of what it means when geneticists talk about human diversity, says Charles Rotimi, a genetic epidemiologist and director of the Center for Research on Genomics and Global Health at the U.S. National Human Genome Research Institute, or NHGRI, in Bethesda, Md. He suggests beginning with "our common ancestry, where we all started before we went to different environments." Because the human genome is able to adapt to different environments, humans carry signatures of some of the geographic locations where their ancestors settled. "We need to understand how this influenced our biology and our history," Rotimi says.

Researchers can work to understand the genetic diversity within our genome "without invoking old prejudices, without putting our own social constructs on it," he says. "I don't think the problem is the genome. I think the problem is humanity."

Lawrence Brody, director of NHGRI's Division of Genomics and Society, agrees: "The scientists of today have to own the discrimination that happened in the generations before, like the Tuskegee experiment, even though we're very far removed from that." During the infamous Tuskegee experiment, African American men with syphilis were not given treatment that could have cured the infection.

"We want the fruits of genetic research to be shared by everyone," Brody says. It's important to determine when genetic differences contribute to disease and when they don't. Especially for common diseases, such as heart disease and diabetes, genetics may turn out to take a back seat to social and economic factors, such as access to health care and fresh foods, for example, or excessive stress, racism and racial biases in medical care. The only way to know what's at play is to collect the data, and that includes making sure the data are as diverse as possible. "The ethical issue is to make sure you do it," Brody says.

> "We want the fruits of genetic research to be shared by everyone."
> LAWRENCE BRODY

Hilliard says that the argument that minorities become more vulnerable when they open themselves to genetic research is valid. "Genomics, like nuclear fusion, can be weaponized and dangerous," she says in response to readers' concerns. "Minorities can choose to be left out of the genomic revolution or they can make full use of it," by adding their genetic data to the mix.

Different priorities

Certain groups are choosing to steer clear, even as scientists try to recruit them into genetic studies. The promise that the communities that donate their DNA will reap the benefits someday can be a hard sell.

"We're telling these communities that this is going to reduce health disparities," says Keolu Fox, a Native Hawaiian and human geneticist at the University of California, San Diego. But so far, precision medicine has not produced drugs or led to health benefits for communities of color, he pointed out last July in the *New England Journal of Medicine*. "I'm really not seeing the impact on [Native Hawaiians], the Navajo Nation, on Cheyenne River, Standing Rock. In the Black and brown communities, the least, the last, the looked over, we're not seeing the ... impact," Fox says.

That's because, "we have a real basic infrastructure problem in this country." Millions of people don't have health care. "We have people on reservations that don't have access to clean water, that don't have the ... internet," he says. Improving infrastructure and access to health care would do much more to erase health disparities than any genetics project could right now, he says.

Many Native American tribes have opted out of genetic research. "People ask, 'How do we get Indigenous peoples comfortable with engaging with genomics?'" says Krystal Tsosie, a member of the Navajo (Diné) Nation, geneticist at Vanderbilt University in Nashville, and cofounder of the Native Biodata Consortium. "That should never be the question. It sounds coercive, and there's always an intent in mind when you frame the question that way." Instead, she says, researchers should be asking how to protect tribes that choose to engage in genetic research.

And issues of privacy become a big deal for small groups, such as the 574 recognized Native American tribal nations in the United States, or isolated religious or cultural groups such as the Amish or Hutterites. If one member of such a group decides to give DNA to a genetic project, that submission may paint a genetic portrait of every member of the group. Such decisions shouldn't be left in individual hands, Tsosie says; it should be a community decision.

Hilliard says minorities' resistance to participating in genetic research is about more than a fear of being singled out; it's the result of being experimented on but seeing medical breakthroughs benefit only white people.

"Medical researchers just need to accomplish something that benefits somebody other than Europeans," she says. "If Blacks or Native Americans or other underrepresented groups saw even a single example of someone of their ethnicity actually being cured of the many [common] chronic diseases and specific cancers for which they are at high risk, that paranoia would evaporate overnight." ■

Explore more

■ Giorgio Sirugo, Scott M. Williams and Sarah A. Tishkoff. "The missing diversity in human genetic studies." *Cell*. March 21, 2019.

This project on ethics and science was supported by the Kavli Foundation.

DELPHINE LEE

To read more on ethics and science, visit **bit.ly/SN_brain-privacy**

Beloved Beasts
Michelle Nijhuis
W.W. NORTON & CO., $27.95

BOOKSHELF

Delve into the history of the fight to save Earth's endangered creatures

On October 29, 1929, a date best remembered for the infamous Black Tuesday stock market crash, socialite and amateur bird watcher Rosalie Edge attended a meeting of the National Association of Audubon Societies. She was there to ask whether it was true, as a pamphlet had claimed, that the organization supported bounties on bald eagles in Alaska and turning wildlife refuges into shooting grounds.

The men who led the organization were outraged that she brought up the issue. But the pamphlet revealed a truth about conservation at the time: The movement was not as much about saving species as it was about saving only certain species that people liked. And sometimes people only liked those species because they liked to kill them.

The idea of conservation has evolved a lot over the last two centuries, as Michelle Nijhuis documents in her new book, *Beloved Beasts: Fighting for Life in an Age of Extinction*. It was only in the mid-1700s that Carl Linnaeus began formalizing the idea of species. The recognition that a species could actually go extinct followed soon after. The push to prevent extinctions from happening came in the 1800s, with the realization that species such as the dodo had disappeared forever. Now we know that humans are driving such losses at a rate not seen for millions of years.

Edge is just one of the many people who Nijhuis highlights in her excellent history. She includes famous names, such as Aldo Leopold, who in the early 20th century shaped the field of wildlife biology and whose writings have influenced generations, and Rachel Carson, whose 1962 book *Silent Spring* inspired huge changes to U.S. environmental laws and the creation of the Environmental Protection Agency. But it's Nijhuis' tales of lesser-known people, such as Edge and Michael Soulé, who is considered the father of conservation biology, that prove most fascinating. Their stories show how a single person can spark big changes, creating organizations and efforts that last for decades and grow to span the globe.

The book truly shines, though, when Nijhuis is brutally honest about how the conservation movement gained a reputation for being antihuman. Prominent conservationists in the 19th and 20th centuries at times endorsed abhorrent practices, such as eugenics. But more often and more subtly, the movement has advocated for actions such as removing Indigenous communities from areas set aside for wildlife.

Nijhuis also recognizes the need to move beyond worrying about saving eagles or any other single species. We must save whole ecosystems, all while balancing human needs, she writes.

One example of such a holistic approach comes from Namibia, home to iconic animals like rhinos and giraffes, where conservation is not a top-down effort guided by governments or organizations with offices on the other side of the planet. It's carried out by dozens of local conservancies that consider the needs of both their local animals and their local people. Through detailed scrutiny, Nijhuis shows that Namibia's model is proving successful.

Past methods of saving species, such as focusing solely on charismatic animals, won't halt what is now recognized by many as Earth's sixth mass extinction. But the book's focus on paths forward provides a bit of hope. That hope springs from collective action: We all must step up to save our planet's beloved beasts. — *Sarah Zielinski*

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The Society for Science's *Science News* in High Schools (*SN*HS) program brings *Science News* magazine and related educational resources to high schools across the United States and worldwide. As teachers continue to navigate the needs of physical classrooms, remote learning or a combination of both, having these materials has never been more important. Read about how *SN*HS educators are using the program resources to keep their students engaged in STEM.

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A smash hit

*In "A complete collection of cosmic smash-ups" (SN: 1/30/21, p. 30), **Emily Conover** and **Nadieh Bremer** visualized every gravitational wave event spotted so far.*

Freelance data visualization designer Nadieh Bremer "reduced an excruciatingly complex subject, gravitational waves produced by cosmic collisions, into a very interesting graphic. Emily Conover made it understandable," reader **Richard Polangin** wrote. "Bravo to your very gifted staff!"

Reader **Dave Proffitt** noticed the colliding black holes were quite massive. "Why no detections in the [mass] range of commonly known black holes?"

It's easier for the LIGO and Virgo observatories to spot more massive mergers because the gravitational waves are larger. "So, it's true that there are a lot of detected events that were quite massive. However, there are a handful of detected events that involve quite small black holes," **Conover** says. One detection, represented in the illustration by the small circle at about 1.6 billion years, resulted from the merger of a black hole with about 8.8 solar masses and a black hole with about five solar masses. "Three solar masses is the lower limit for what can be confidently called a black hole," she says. "You can't get smaller than that without it being difficult to determine whether it's a black hole or a neutron star."

Left out

*Scientists are getting inventive with ways to touch down on Earth's neighbors, **Lisa Grossman** reported in "How to safely land on Venus or Europa" (SN: 1/30/21, p. 12).*

Reader **Michael Stebel** was disappointed that the story did not mention the Huygens probe, which landed on Saturn's moon Titan in 2005. "Although [the probe] sent back data and images for less than six hours, it was an incredible achievement ... especially notable when one considers the distance involved, the extreme cold and the thick hazy atmosphere of Titan," he wrote.

A colorful story of wildfire recovery

Each year in California, wildfires ravage hundreds of thousands of hectares of land. Deciphering how well large swaths of vegetation recover over time can be tough from the ground. Radar maps now reveal the patchwork of plant destruction and regrowth in the wake of more than a decade of fires near Los Angeles.

A NASA research plane equipped with radar instruments flew over Angeles National Forest many times from 2009 to 2020 to produce a detailed view (shown) of the terrain. The radar pulses are sensitive to moisture and changes in physical features, says Yunling Lou, a radar engineer at NASA's Jet Propulsion Laboratory in Pasadena, Calif. The resulting maps distinguish bare earth from trees and shrubs.

Lou and colleagues are color-coding maps by year to monitor the recovery of forests and shrubland after wildfires. Red denotes areas with vegetation in 2010, green is 2017 and blue is 2020. When maps for those three years are laid atop each other, they tell a story of loss and regrowth. After fires in 2014 and 2016, vegetation had not grown back by 2017 or 2020, so those areas appear red. The bright yellow tract shows the area affected by the 2020 Bobcat Fire, where vegetation was present only in 2010 and 2017 (red and green make yellow). Green and blue regions show areas with more plant growth in recent years.

The color-coding could allow researchers to identify factors, such as vegetation and soil type, that explain why areas regenerate at different speeds. Such maps could also potentially be used to identify burned regions without vegetation that are at risk for landslides. — *Jack J. Lee*

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