Goldfish Learn To Drive | An Exomoon Find?

# Science News MAGAZINE OF THE SOCIETY FOR SCIENCE • FEBRUARY 12, 2022

# The Human Blueprint

Our DNA is full of fascinating stories, and we've only begun to read them

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## Features

- **16** Military Lessons on Integration Seeking troop cohesion and readiness, the U.S. military pushed to desegregate itself, leading to integration of some of the towns surrounding its bases. Can the civilian world learn to do the same? By Sujata Gupta
- 22 Reading Our Genes

**COVER STORY** The past century witnessed a stunning achievement: the unveiling of the human genetic instruction book. In a conversation with Eric Green, a leader in genomics research, staff writer Tina Hesman Saey explores today's genomics landscape.

## News

- 6 Extreme rainfall and drought impact global manufacturing and service sectors
- 7 A tree-planting project in northern Africa could have a powerful effect on the region's climate
- 8 Swapping spit may cue babies in on close relationships

Latest cosmic "Cow" explosion is the brightest one yet found

- 9 MRSA superbug evolved in hedgehogs long before the antibiotic era, an analysis suggests
- **10** A Martian meteorite's organic molecules were probably formed via geology, not alien life

An eerie quantum effect of magnetic fields also applies to gravity

**12** The largest colony of nesting fish ever found is roughly the size of Orlando

Similarities between the human and dolphin clitoris suggest the cetaceans experience sexual pleasure

- **13** Some volcanic hot spots may have shallow roots
- 14 News in Brief Loss of smell in some people with COVID-19 may be tied to genetic variants

Volcanic avalanches pack destructive wallops that come in waves

East Africa's oldest known *Homo sapiens* fossils are even older than scientists thought

Astronomers ID another potential moon orbiting an exoplanet



Departments 2 EDITOR'S NOTE

- 4 NOTEBOOK Goldfish can drive "cars"; early warning of a star's demise spotted
- 29 REVIEWS & PREVIEWS A new book explores competing theories about the first Americans
- 31 FEEDBACK
- 32 SCIENCE VISUALIZED How tiny beetles match the flight speed of much larger insects

**COVER** The iconic double helix, the structure of our DNA, has graced the cover of *Science News* many times. *Jeremy Leung* 





## How machines help us decipher our genes

Back in the 1990s. I toured MIT's Whitehead Institute in Cambridge, Mass., one of the key players in the Human Genome Project. The massive project was the life sciences equivalent of putting people on the moon. In a large room, rows and rows of big beige machines, automated gene

sequencers, hummed along, churning their way through DNA. If this was a scientific revolution, it was a very quiet one.

That quiet belied the decades of human sweat and technological innovation that made it possible to identify and catalog the genetic instructions for a human. But Tina Hesman Saey, a senior writer and molecular biology reporter for Science News, remembers the effort required all too well.

When Saey started working in laboratories as an undergraduate, scientists identified the bases in DNA sequences through a laborious process. The work required her to be part short-order cook, part chemist, part X-ray technician and part medieval scribe. Tasks involved heating polyacrylamide in a microwave to make sheets of gel more than 300 millimeters across and just a few millimeters thick, adding bits of DNA tagged with radioactive isotopes and using electric current to push DNA molecules through the gel, with smaller molecules moving faster than larger ones. Next, the gels had to be doused with chemicals and exposed to giant cassettes of X-ray film, and the film had to be developed. "I used to have nightmares that something went wrong and I couldn't get into the darkroom to develop my film," Saey told me.

The end result was X-ray film laddered with black and gray smudges - DNA bases that a person then had to manually identify and record, one at a time. "You would just go along taking it from the bottom," Saey says, "following each step up the ladder to determine the sequences."

On a good day, Saey could identify 50 to 100 bases on one gel. Now, robots and automated high-throughput sequencers make it possible to read millions of bases at a time, with computers ID'ing the bases and packaging the data in a tidy digital file. "The robots took over all the tedious precision work," Saey says. "People were freed up to do the analytical work."

In this issue, Saey talks with Eric Green, director of the National Human Genome Research Institute, about the origins of the Human Genome Project and what remains to be discovered (Page 22). The answer: plenty.

Among the many surprises that emerged from the project is how much we didn't know about our DNA, including the importance of what before had been thought to be mere "junk" DNA. It's a delight to see Green and Saey geek out over their fascination with noncoding RNAs, and their excitement over the many mysteries to be explored. I also learned that they worked in laboratories on the same hallway while Saey was a graduate student at Washington University in St. Louis. It's a small world.

This conversation about the genomics revolution is part of our Century of Science project, which celebrates the 100th anniversary of Science News by exploring key scientific advances. There's plenty more to marvel over at www.sciencenews.org/century. - Nancy Shute, Editor in Chief

PUBLISHER Maya Ajmera EDITOR IN CHIEF Nancy Shute

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Pr

## How to Win at Love

#### A classic tennis bracelet serves up over 10 carats of sparkle f

It was the jewelry piece that made the world stop and take notice. In the middle of a long volley during the big American tennis tournament, the chic blonde athlete had to stop play because her delicate diamond bracelet had broken and she had to find it. The tennis star recovered her beloved bracelet, but the world would never be the same.

From that moment on, the tennis bracelet has been on the lips and on the wrists of women in the know. Once called eternity bracelets, these bands of diamonds were known from then on as tennis bracelets, and remain *the* hot ticket item with jewelers.

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#### NOTEBOOK



Excerpt from the February 12, 1972 issue of *Science News* 

#### 50 YEARS AGO

## Probing Venus' mountains

Venus' perpetually cloudshrouded surface remains penetrable only by radio waves. A planetary radar group now reports results of an extended series of radar measurements of the topography of Venus that for the first time provides a view of surface height variations around the entire circumference of the planet.

**UPDATE:** Those observations were taken by the Arecibo radio telescope in Puerto Rico, which was the most powerful radar system for mapping rocky bodies in outer space until its sudden collapse in December 2020 (SN: 12/19/20 & 1/2/21, p. 8). The observatory also revealed ancient lava flows on Venus and ice on Mercury (SN: 9/18/76, p. 181; SN: 11/9/91, p. 295). Arecibo's maps of Mars and the asteroid Bennu helped NASA plan the Viking and OSIRIS-REx missions. Some other facilities have planetary radar systems. but they are not as powerful as Arecibo's was. Astronomers are adding a radar transmitter to West Virginia's Green Bank Telescope that is expected to rival or exceed Arecibo's.

#### HOW BIZARRE

## Goldfish drivers reveal navigation know-how

It might seem like a fish needs a car like — well, like a fish needs a bicycle. But a new experiment suggests that fish actually make pretty good drivers.

In the experiment, several goldfish learned to drive what is essentially the opposite of a submarine — a tank of water on wheels — to destinations in a room. That these fish could maneuver on land suggests that a fish's understanding of space and navigation is not limited to its natural environment — and perhaps has something in common with landlubber animals' internal sense of direction, researchers report in the Feb. 15 *Behavioural Brain Research*.

Researchers at Ben-Gurion University of the Negev in Beer-Sheva, Israel, taught six goldfish to steer a motorized water tank. The fishmobile was equipped with a camera that continuously tracked a fish driver's position and orientation inside the tank. Whenever the fish swam near one of the tank's walls, facing outward, the vehicle trundled off in that direction.

Fish were schooled on how to drive during about a dozen 30-minute sessions. The team trained each fish to drive from the center of a small room toward a pink board on one wall by giving the fish a treat when it reached the wall. During their first sessions, fish averaged about 2.5 successful trips to the target. During their final sessions, fish averaged about 17.5 successful trips. By the end of driver's ed, the animals took faster, more direct routes to their goal.

Some of the fish — all named after *Pride* and *Prejudice* characters — were speedier learners than others. "Mr. Darcy was the best," says neuroscientist Ronen Segev.

In further tests, the goldfish were even able to reach the pink board when starting from random positions around the room, rather than the center. This finding confirmed that the fish had not merely memorized a choreography of movements to reach their reward but were planning routes toward their prize each time. When the team tried to trick the goldfish by hanging boards of different colors on different walls or moving the pink board across the In a recent experiment, goldfish learned how to drive a motorized water tank.

room, the fish still drove to the pink board.

"That was pretty conclusive that the fish actually navigate," says study coauthor and computer scientist Ohad Ben-Shahar. Recently, the team let a goldfish take a joyride through an entire building, Ben-Shahar says, "and it actually started to explore. It went down one of the corridors and started to sneak away."

Behavioral neuroscientist Kelly Lambert is "not completely surprised but still intrigued" by the driving abilities of Mr. Darcy and his fish friends. In her own research at the University of Richmond in Virginia, Lambert has taught rats to drive toy cars. But teaching goldfish to navigate such alien terrain takes animal driving experiments to the next level, Lambert says. "I love the fish out of water idea."

When it comes to testing the bounds of animal navigation, "it's important to diversify and expand our tasks and our species," Lambert says. "I think we need an international race between the rats and the goldfish." — Maria Temming

### Faint outburst foretells a star's doom

A star's death usually comes without warning. But an early sign of one star's imminent demise hints at what happens before some stellar explosions.

In a last hurrah before exploding, a star brightened, suggesting that it blasted some of its outer layers into space. It's the first time scientists have spotted a pre-explosion outburst from a run-of-the-mill type of exploding star, or supernova, researchers report in the Jan. 1 *Astrophysical Journal*.

Scientists have previously seen harbingers of unusual types of supernovas. But "what's nice about this one is it's a much more normal, vanilla ... supernova," says astronomer Mansi Kasliwal of Caltech, who was not involved in the work.

In September 2020, astrophysicist Raffaella Margutti of the University of California, Berkeley and colleagues spotted the explosion of a star roughly 10 times as massive as the sun, located about 120 million light-years from Earth. Thankfully, other telescopes had been observing the star well before it detonated. About 130 days before the explosion, the star In a first, scientists have seen an outburst from a star (illustrated) that signaled it would explode in a common type of supernova.

brightened, the start of a preexplosion eruption.

The final explosion was a type 2 supernova, which occurs when an aging star's core collapses. Precursors to these explosions probably hadn't been spotted before, the team suspects, because the eruptions are too faint for many telescopes to see.

Previous observations of type 2 supernovas have hinted that the stars slough off layers before death. In 2021, astronomers reported signs of a supernova's shock wave plowing into material that the star had expelled (*SN: 12/4/21, p. 15*). Margutti and colleagues found a similar sign of cast-off stellar material.

Researchers aren't sure what causes the early outbursts. But if more such events are found, scientists may be able to predict which stars will go boom, and when. – *Emily Conover* 

#### THE -EST

### Ancient equine was a human-made hybrid

The list of human-made hybrid animals is long and, it turns out, even more ancient than scientists thought. The kunga - an equine that existed in Syro-Mesopotamia around 4,500 years ago - is a cross between a donkey and a type of Asiatic wild ass, making it the earliest known hybrid animal bred by people, paleogeneticist Eva-Maria Geigl and colleagues report in the Jan. 14 Science Advances. Domesticated horses didn't appear in this region of Asia until 4,000 years ago. But dozens of equine skeletons found at a royal burial site in northern Syria date back to about 2600 B.C. The animals, whose features don't match any known equine species, appear to be kungas: horselike animals seen in artwork and referenced in clay tablets that predate domesticated horses by centuries. Geigl's team analyzed one skeleton's genome and compared it with those of horses, donkeys and Asiatic wild asses including the extinct hemippe. The kunga's mother was a donkey and its father a hemippe, making it the oldest evidence of humans creating hybrid animals. A mule from 1000 B.C. in Anatolia, reported by the same research group in 2020, is the next oldest hybrid. Geigl, of Institut Jacques Monod in Paris, thinks kungas were bred for warfare. – Jake Buehler

A Sumerian artifact called the Standard of Ur includes images of kungas pulling wagons (shown). The animals, hybrids of donkeys and wild asses, may have been bred for warfare.



#### TEASER

## A disinfectant may get its oomph from sawdust

A new, sustainable disinfectant made from sawdust and water can knock out more than 99 percent of some pathogens, including anthrax and several strains of flu.

Some disinfectants rely on a compound called phenol or chemical look-alikes that can be costly and energy-intensive to make. But phenolic structures abound in wood as part of molecules that make up plant cell walls. Researchers in China wondered if sawdust waste could provide a greener source of these compounds.

The team pressure-cooked mixtures of water and sawdust for one hour, filtered the concoctions and tested them for their ability to kill infection-causing skin and gut bacteria, anthrax and influenza viruses. Depending on the disinfectant's levels of phenol-like compounds, it could zap more than 99 percent of the pathogens, the team reports in the Jan. 18 *Proceedings of the National Academy of Sciences*. The pressure cooker treatment probably breaks the wood's molecular chains, freeing up antimicrobial phenolic molecules. – *Carolyn Wilke* 

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EARTH & ENVIRONMENT

## Rainfall extremes shock the economy

Drought and floods affect manufacturing more than agriculture

#### **BY CAROLYN GRAMLING**

Extremes in rainfall — whether intense drought or flash floods — can catastrophically slow the global economy, a new study finds. And those impacts are most felt by wealthy, industrialized nations, researchers report in the Jan. 13 *Nature*.

In a global analysis of rainfall's effects on economic output over 40 years, episodes of intense drought led to the biggest shocks to economic productivity. But days with intense deluges - such as occurred in Europe in July 2021-also produced strong shocks to the economic system. Most surprising, though, was that agricultural economies appeared to be relatively resilient against both of these types of shocks, says Maximilian Kotz, an environmental economist at the Potsdam Institute for Climate Impact Research in Germany. Instead, two other business sectors - manufacturing and services - were the most hard-hit.

As a result, the nations most affected by rainfall extremes weren't those that tended to be poorer, with agriculturedependent societies, but the wealthiest nations, whose economies are tied more heavily to manufacturing and services, such as banking, health care and entertainment.

It's well-known that rising temperatures can take a toll on economic productivity, for example, by contributing to increased doctor visits or missed workdays. Extreme heat also has clear impacts on human behavior (*SN*: 9/11/21, *p. 14*). But what effect climate change–caused shifts in rainfall might have on changes in the global economy hasn't been so straightforward.

That's in part because previous studies looking at a possible connection between rainfall and productivity have focused on changes in yearly precipitation, a time frame that "is just too coarse to really describe what's actually happening [in] the economy," Kotz says. Such studies have shown that more rain in a given year is basically beneficial, which makes sense in that having more water available is good for agriculture and other human activities, Kotz says. "But these findings were mainly focused on agriculturally dependent economies and poorer economies."

In the new study, Kotz and colleagues looked at three timescales — annual, monthly and daily rainfall — and examined what happened to economic output for time periods in which the rainfall deviated from average historical values. The analysis included two measures not considered in previous studies, Kotz says: the amount of rainy days that a region gets in a year and extreme daily rainfall. The team then examined these factors across 1,554 regions globally — which included many subregions within 77 countries — from 1979 to 2019. Heavy rains, like those that caused severe flooding in Alexandria, Va., on October 29, 2021, can disrupt global economics, a new study suggests.

The disparity over which regions were hit hardest is "at odds with the conventional wisdom" — and with some previous studies — that agriculture is vulnerable to extreme rainfall, atmospheric scientist Xin-Zhong Liang of the University of Maryland in College Park wrote in a commentary in the same issue of *Nature*. Researchers may need to incorporate other factors in future assessments, such as growth stages of crops, land drainage or irrigation, to really understand how these extremes affect agriculture, Liang wrote.

"That was definitely surprising for us as well," Kotz says. The study doesn't specifically try to answer why manufacturing and services were so affected, but it makes intuitive sense, he says. Flooding, for example, can damage infrastructure and disrupt transportation, effects that can then propagate along supply chains. "It's feasible that these things might be most important in manufacturing, where infrastructure is very important, or in the services sectors, where the human experience is very much dictated by these daily aspects of weather and rainfall," Kotz says.

Including daily and monthly rainfall extremes in this type of analysis is "an important innovation" because it reveals new economic vulnerabilities, says Tamma Carleton, an environmental economist at the University of California, Santa Barbara. However, Carleton says, the findings "are not yet conclusive on who is most vulnerable and why, and instead raise many important questions for future research to unpack."

Extreme rainfall events, including both drought and deluge, will occur more frequently as global temperatures rise, the United Nations' Intergovernmental Panel on Climate Change noted in August (*SN: 9/11/21, p. 8*). The new findings offer yet another stark warning to the industrialized, wealthy world, Kotz says. Human-caused climate change will have "large economic consequences."

#### EARTH & ENVIRONMENT

## How Africa's 'Great Green Wall' could alter climate

Planting trees in the Sahel may intensify the regional monsoon

#### **BY CAROLYN GRAMLING**

Africa's "Great Green Wall" initiative is a proposed 8,000-kilometer line of vegetation meant to hold back the Sahara from expanding southward. Climate simulations looking to both the region's past and future suggest this greening could have a profound effect on the climate of northern Africa, and even beyond.

By 2030, the project aims to plant 100 million hectares of trees and shrubs along the Sahel, the semiarid zone lining the desert's southern edge. Once completed, the greenbelt could double rainfall within the Sahel and decrease average summer temperatures throughout much of northern Africa and into the Mediterranean, according to the simulations, presented December 14 at the American Geophysical Union's fall meeting. One concern: Temperatures in the hottest parts of the desert could rise.

Previous studies have shown that a "green Sahara" is linked to changes in the intensity and location of the West African monsoon. That major wind system blows hot, dry air southwestward across northern Africa during the cooler months and brings slightly wetter conditions northeastward during the hotter months.

Such changes in the monsoon's inten-

sity and its northward or southward extent led to a green Sahara period that lasted from about 11,000 to 5,000 years ago, for example (*SN: 2/18/17, p. 18*).

Past changes in the monsoon are tied to cyclical variations in Earth's orbit, which alters how much incoming solar radiation heats up the region. But orbital cycles don't tell the whole story, says Francesco Pausata, a climate dynamicist at the Université du Québec à Montréal who ran the new simulations. Scientists now recognize that changes in plant cover and overall dustiness can dramatically intensify monsoon shifts, he says.

More vegetation "helps create a local pool of moisture," with more water cycling from soil to atmosphere, increasing humidity and therefore rainfall, says Deepak Chandan, a paleoclimatologist at the University of Toronto who wasn't involved in the work. Plants also make for a darker land surface compared with blinding desert sands, so the ground absorbs more heat, Chandan says. What's more, vegetation reduces how much dust is in the atmosphere. Dust particles can reflect sunlight back to space, so less dust means more solar radiation can reach the land. Add it all up. and these effects lead to more heat and more humidity over the land relative to the ocean, creating a larger difference in atmospheric pressure. And that means stronger, more intense monsoon winds will blow.

The idea for Africa's Great Green Wall took root in the 1970s and '80s, when the once-fertile Sahel began to turn barren and dry as a result of changing climate and land use. Planting a protective wall of vegetation to hold back an expanding

The Sahara's southern edge is bordered by a semiarid zone called the Sahel (shown here in Mali). The "Great Green Wall" project aims to stop desertification by adding more greenery to this region.



desert is a long-standing scheme. Since the '70s, China has engaged in its own desert vegetation project — also nicknamed the Great Green Wall — in an attempt to halt the southward march of the Gobi Desert (SN: 7/3/21 & 7/17/21, p. 19).

Led by the African Union, Africa's Great Green Wall project launched in 2007 and is now about 15 percent complete. Proponents hope the finished tree line, which will extend from Senegal to Djibouti, will not only hold back the desert, but also bring improved food security and millions of jobs.

What effect the finished greening might have on the local, regional and global climate has been little studied but it needs to be, Pausata says. The initiative is essentially a geoengineering project, he says, and when people want to do any type of geoengineering, they should study the possible impacts.

To investigate possible impacts, Pausata created high-resolution computer simulations of future climate change, both with and without a Great Green Wall. Against the backdrop of climate change, the greenbelt would decrease average summer temperatures in most of the Sahel by as much as 1.5 degrees Celsius.

But the Sahel's hottest areas would get even hotter, with average temperatures increasing by as much as 1.5 degrees. The greening would also increase rainfall across the entire region, even doubling it in some places, the research suggests.

These results are preliminary and are for a high-emissions future warming scenario that may not end up matching reality, Pausata says. Simulations for moderate- and lower-emissions scenarios are ongoing.

The effects of greening the Sahara might extend far beyond the region, the simulations suggest. A stronger West African monsoon could shift larger atmospheric circulation patterns westward, influencing other climate patterns such as the El Niño Southern Oscillation and altering the tracks of tropical cyclones.

That the Great Green Wall's impact could be far-ranging makes sense, Chandan says: "The climate system is full of interactions."

# Babies may look to saliva to infer bonds

Kissing or sharing food may cue kids in on close relationships

#### **BY ERIN GARCIA DE JESÚS**

Young children are always watching including when people swap spit through actions like food sharing. Such behavior helps tots infer who is in close relationships with one another, a study suggests.

Typically, people are more likely to engage in activities that can lead to an exchange of saliva, such as kissing or sharing an ice cream cone, with family members or close friends than with an acquaintance or colleague. So saliva sharing can be a marker of "thick relationships," or people who have strong attachments, says MIT developmental psychologist Ashley Thomas.

To see if young children might use saliva sharing as a social cue for intimate bonds, Thomas and colleagues ran experiments of people engaging with puppets. When shown a puppet seemingly crying, kids as young as 8 months old were more likely to look at an adult who had previously shared saliva with the puppet than at an adult who hadn't, the team reports in the Jan. 21 *Science*.

Scientists, of course, can't know exactly what babies are thinking. But tracking where they look offers hints. The team used where the kids looked first when a puppet showed distress as a proxy for their understanding of the relationship.

In some experiments, the team showed 8- to 10-month-olds or 16- to 18-montholds videos of a woman sharing an orange slice with a puppet. A second video depicted another woman and the puppet playing with a ball. During a final video, which showed the puppet crying while seated between the two women, the kids' eyes were more often drawn to the woman who had shared the orange.

The team saw similar results when one woman interacted with two puppets. The woman stuck her finger in her mouth and then in one puppet's mouth to share saliva. For the other, she touched only her forehead and then the puppet's forehead. After the woman showed distress, kids spent more time looking at the puppet that had seemingly swapped saliva.

It's unclear how the findings relate to children's daily lives. Future studies could switch out actresses for family members or teachers to better understand the role saliva may play in distinguishing relationships. Other cues, such as hugging, may also play a role, Thomas says.

The study focused only on U.S. children. Still, the work is exciting, says clinical developmental psychologist Darby Saxbe of the University of Southern California. It would be interesting, she says, to see how kids from groups that have different hygiene or eating traditions react.

#### ATOM & COSMOS

# Astronomers find another 'Cow'

Discovery offers clues to what powers these cosmic blasts

#### **BY LIZ KRUESI**

A blast from a galaxy some 2 billion lightyears from Earth is the brightest cosmic "Cow" yet found. It's the fifth known object in this class of exploding stars and their long-glowing remnants, and it's giving hints to what powers them.

Cow-like events — named for the first such object found, in 2018, which had the unique identifier name of AT2018cow — are a rare subclass of supernovas. They brighten quickly, glow brilliantly in ultraviolet and blue light, and linger for months in higher-energy X-rays and lower-energy radio waves.

X-rays from the new discovery, dubbed AT2020mrf, glowed 20 times as brightly as those from the original Cow about a month after the blast, Caltech astronomer Yuhan Yao reported January 10 at a news briefing held by the American Astronomical Society. Even a year after the discovery of the new object, its X-rays were 200 times as bright as those from the Cow a year post-discovery.

The Zwicky Transient Facility at Caltech's Palomar Observatory noted a bright new burst of light on June 12, 2020, but no one realized what it was.

In April 2021, researchers with the Spectrum-Roentgen-Gamma, or SRG, telescope, which studies X-ray light, alerted Yao and colleagues to a signal from July 21–24, 2020, at the same spot in the sky. "I almost immediately realized that this might be another Cow-like event," Yao says. Yao's group then looked at that spot with multiple observatories.

The Chandra X-ray Observatory captured X-rays in June 2021, a year after the original blast. The signal "was 10 times brighter than what I expected,"Yao says.

The strengths of the Chandra and the SRG X-ray signals changed within hours to days. "The duration of [that flaring] gives you a sense of how compact or how



A Cow-like supernova (illustrated) may leave behind a black hole or a neutron star.

big the object is," says MIT astrophysicist DJ Pasham, who studied the original Cow but wasn't part of this study.

A compact object like an actively eating black hole or a rapidly spinning, highly magnetic neutron star would create strong, variable X-ray signals, Yao says. These were the most probable leftover remnants of the original Cow, but the new find provides even greater certainty.

Catching these events earlier in the act with multiple types of light will help reveal more about what type of star explodes as a Cow.

## Drug resistance traced to hedgehogs

Some MRSA strains originated before the use of antibiotics

#### **BY CAROLYN WILKE**

Beneath the prickly spines of European hedgehogs, a microbial standoff may have bred a dangerous drug-resistant pathogen long before the era of antibiotic use by humans.

There's no question that antibiotic use accelerates drug resistance in the bacteria that colonize humans, says Jesper Larsen, a veterinarian at Statens Serum Institut in Copenhagen. But, he says, these microbes had to get the genes that give them resistance from somewhere, and scientists don't know where most of these genes come from.

For one type of methicillin-resistant *Staphylococcus aureus*, or MRSA, Larsen and colleagues have tracked its evolution to hedgehogs hundreds of years ago. On the skin of these critters, a fungus that produces natural antibiotics may have created the environment for drug resistance to evolve, the researchers report January 5 in *Nature*.

MRSA, one of the most common drugresistant pathogens, infects hundreds of thousands of people each year in the United States alone. The type of MRSA that the new study focuses on causes a small fraction of cases.

The team first found MRSA in hedgehogs by coincidence years ago when coauthor Sophie Rasmussen, a biologist who is now at the University of Oxford, approached Larsen's team about sampling a freezer full of dead hedgehogs collected in Denmark. Sixty-one percent carried MRSA. "We found this extremely high prevalence," Larsen says, suggesting that hedgehogs were a reservoir for the drug-resistant superbug.

In the new work, the scientists surveyed two species of hedgehogs, *Erinaceus europaeus* and *E. roumanicus*, from 10 European countries and New Zealand. Workers at wildlife rescue centers swabbed the noses, skin and feet of 276 animals. MRSA was prevalent in hedgehogs in the United Kingdom, Denmark and the Czech Republic.

The researchers found 16 strains of *mecC*-MRSA, named after the gene that confers resistance, and mapped the evolutionary relationships between the strains by comparing mutations across their genomes. The team inferred that the three oldest lineages emerged 130 to 200 years ago in hedgehog populations, periodically infecting people and cattle long before penicillin hit the market in the 1940s. Hedgehogs may be the source of nine out of the 16 lineages.

"There is no doubt that our usage of antibiotics is the main driver of resistance in human pathogens," says coauthor Anders Larsen, a microbiologist

 Workers at wildlife rescue centers swabbed the noses, skin and feet of hundreds of European hedgehogs (like the one shown), revealing that many of the critters harbored a type of MRSA superbug.

at Statens Serum Institut. "This is a very special case where we can just track it back to an origin."

But that doesn't explain how the hedgehogs' *S. aureus* developed resistance. The team got a clue from a 1960s study of *Trichophyton erinacei*, a fungus that causes "hedgehog ringworm" in humans. That study reported that *T. erinacei* on hedgehog skin killed some *S. aureus* but didn't kill strains that were resistant to penicillin. Growing *T. erinacei* in the lab, the researchers in the new study identified two penicillinlike antibiotics pumped out by the fungi.

This finding suggests that hedgehogs are a MRSA reservoir because "they're living cheek by jowl with organisms that are producing penicillin," says Gerry Wright, a biochemist at McMaster University in Hamilton, Canada, who was not involved with the study.

The fungi "live in a bad neighborhood," he says. They have to compete with other microbes, such as *S. aureus*, for resources and a spot to colonize on the host. "They have to work out this arrangement where they can protect themselves," he says.

You can't think about antibiotic resistance without considering environmental connections, Wright says. The evolution of resistance is a gradual process shaped by natural selection, he says. Wright's work has shown that in places that have escaped human influence, antibiotic resistance has ancient origins. People have searched for this evolution mostly in the soil microbial community, or microbiome. But the microbiomes of animals provide another potential source for the genes that confer resistance, as well as for sources of new antibiotics, he says.

The history of antibiotics in the last century is a cycle of new drug discoveries followed shortly by microbial resistance to those drugs cropping up. That shouldn't be a surprise, Wright says, "because antibiotics have been on the planet for billions of years, and resistance is billions of years old." If scientists don't better understand where resistance comes from, even as researchers discover new drugs, he says, all we'll be doing is playing catch-up.

## ATOM & COSMOS Meteorite's organics aren't signs of life

Geologic processes could explain molecules in Martian rock

#### **BY NIKK OGASA**

When scientists in 1996 reported finding organic molecules in an ancient Martian meteorite discovered in Antarctica, it caused quite a buzz. Some insisted the compounds were evidence of life having once existed on Mars. Others, though, pointed to contamination by earthly lifeforms or a nonbiological origin.

Now, a geochemical analysis of the meteorite provides the latest buzzkill to the idea that the 4.09-billion-year-old fragment of the Red Planet holds signs of alien life. Instead, the meteorite's organic matter probably formed from the chemical interplay of water and minerals mingling at or under Mars' surface, researchers report in the Jan. 14 *Science*.

Even so, the finding could aid in the search for past or present life on Mars, the team says.

Organisms often produce organic molecules, but the molecules can also arise from nonbiological, or abiotic, processes. Though myriad hypotheses seek to explain what sparked life on Earth, many researchers consider abiotic organic molecules to be necessary starting material. Martian geologic processes could have been generating these compounds for billions of years, the new study suggests.

"These organic chemicals could have become the primordial soup that might have helped form life on [Mars]," says biochemist Andrew Steele of the Carnegie

The ancient Martian meteorite ALH84001, discovered in Antarctica in 1984, contains organic molecules that researchers now say were formed by geologic processes rather than by alien organisms. Institution for Science in Washington, D.C. Whether life ever existed there, however, remains unknown.

Steele and colleagues sought to study how ancient Martian water may have altered minerals in the meteorite, known as ALH84001. In small samples of the meteorite, the team discovered by-products of two chemical reactions serpentinization and carbonation, which occur when fluids interact with minerals and transform them. Amid these by-products, the researchers detected complex organic molecules. Based on the identification of these two processes, the team concluded the organics probably formed during the reactions, just as they do on Earth.

The relative amounts of different types of hydrogen in the organic matter supported the notion that the organic compounds developed while on Mars; they didn't emerge from Earth's microbes or materials used in the experiments.

The study is not the first to propose that organic material in Martian rocks could form without life. Researchers attributed the formation of complex organics in the 600-million-year-old Tissint meteorite, also from Mars, to chemical interactions of water and rock.

However, ALH84001 is one of the oldest Martian meteorites ever found. The new findings, when considered alongside other evidence, suggest that abiotic processes have been generating organic material on Mars for much of its history, says Mukul Sharma, a geochemist at Dartmouth College. "Nature has had a huge amount of time on its hands to produce this stuff."

Identifying abiotic sources of organic compounds on the Red Planet is crucial to the search for life, Steele says. Once you've figured out how Martian organic chemistry acts without meddlesome life, he says, "you can then look to see if it's been tweaked."

#### MATTER & ENERGY

## Eerie quantum effect confirmed

Gravitational fields can affect particles they never touch

#### **BY EMILY CONOVER**

If you're superstitious, a black cat in your path is bad luck, even if you keep your distance. Likewise, in quantum physics, particles can feel the influence of magnetic fields that they never come into direct contact with. Now scientists have shown that this eerie quantum effect holds not just for magnetic fields, but for gravity too — and it's no superstition.

Usually, to feel the influence of a magnetic field, a particle would have to pass through it. But in 1959, physicists Yakir Aharonov and David Bohm predicted that, in a specific scenario, the conventional wisdom would fail. A magnetic field contained within a cylindrical region can affect particles – electrons, in their example – that never enter the cylinder. In this scenario, the electrons don't have well-defined locations but are in "superpositions," quantum states described by the odds of a particle materializing in one of two different places. Each fractured particle simultaneously takes two different paths around the magnetic cylinder. Despite never touching the electrons, and hence exerting no force on them, the magnetic field shifts the pattern of where the particles are found at the end of this journey, as various experiments have confirmed (SN: 3/1/86, p. 135).

In the new experiment, the same uncanny physics is at play for gravitational fields, physicists report in the Jan. 14 *Science*. "Every time I look at this experiment, I'm like, 'It's amazing that nature is that way,'" says physicist Mark Kasevich of Stanford University.

Kasevich and colleagues launched rubidium atoms inside a 10-meter-tall vacuum chamber, hit them with lasers to put them in quantum superpositions tracing two different paths, and watched how the atoms fell. Notably, the atoms weren't in a gravitational field-free zone. Instead, the experiment was designed so that the researchers could filter out the effects of gravitational forces, laying bare the eerie Aharonov-Bohm influence.

The study not only reveals a famed physics effect in a new context, but also showcases the potential to study subtle effects in gravitational systems. For example, researchers aim to use this type of technique to better measure Newton's gravitational constant, G, which reveals the strength of gravity and is currently known less precisely than other fundamental constants of nature (*SN*: 9/29/18, p. 8).

A phenomenon called interference is key to the new study. In quantum physics, atoms and other particles behave like waves that can add and subtract, just as two swells merging in the ocean make a larger wave. At the end of the atoms' flight, the scientists recombined the atoms' two paths so their waves would interfere, then measured where the atoms arrived. The arrival locations According to the general theory of relativity, gravity results from massive objects warping spacetime (illustrated). A quantum effect reveals that subatomic particles can feel the influence of this warping even if they aren't subject to gravitational forces.

are highly sensitive to tweaks that alter where the peaks and troughs of the waves land, known as phase shifts.

At the top of the vacuum chamber, the researchers placed a hunk of tungsten with a mass of 1.25 kilograms. To isolate the Aharonov-Bohm effect, the scientists performed the same experiment with and without this mass, and for two different sets of launched atoms. one which flew close to the mass and the other lower. Atoms in each of those two sets were split into superpositions, with one path traveling closer to the mass than the other, separated by about 25 centimeters. Other sets of atoms. with superpositions split across smaller distances, rounded out the crew. Comparing how the various sets of atoms

interfered, both with and without the tungsten mass, teased out a phase shift that was not due to the gravitational force. Instead, that tweak was from time dilation, a feature of Einstein's theory of gravity, general relativity, which causes time to pass more slowly close to a massive object.

The two theories that underlie this experiment, general relativity and quantum mechanics, don't work well together. Scientists don't know how to combine them to describe reality. So, for physicists, says Guglielmo Tino of the University of Florence, who was not involved with the new study, "probing gravity with a quantum sensor, I think it's really one of ... the most important challenges at the moment."



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# Colossal fish colony found in Antarctica

Millions of icefish nests span an area nearly the size of Orlando

#### **BY JAKE BUEHLER**

Five hundred meters below the ice covering Antarctica's Weddell Sea is the world's largest known colony of breeding fish.

An estimated 60 million active icefish nests stretch across at least 240 square kilometers, nearly the size of Orlando, Fla., researchers report January 13 in *Current Biology*. Many kinds of fish create nests, but until now, even the most gregarious nest builders were known to gather only in the hundreds.

## Dolphin clitoris is much like humans'

Sexual pleasure may explain why dolphins are so randy

#### BY LESLEY EVANS OGDEN

Dolphins have active sex lives, with frequent dalliances not just for reproduction. One reason may be that the dolphin clitoris, a new study suggests, provides sexual pleasure.

An up-close look at clitoral tissue from female common bottlenose dolphins (*Tursiops truncatus*) reveals many similarities to the human clitoris. Abundant sensory nerves and spongy tissues suggest the dolphin clitoris is very sensitive to physical contact, researchers report in the Jan. 10 *Current Biology*. The icefish probably have a substantial and previously unknown influence on Antarctic food webs, the researchers say.

Deep sea biologist Autun Purser of the Alfred Wegener Institute in Bremerhaven, Germany, and colleagues stumbled across the colony in 2021 while on a research cruise in the Weddell Sea, located between the Antarctic Peninsula and the main continent. The research involved surveying seafloor life by towing a device behind an icebreaking research vessel.

Thus, the bottlenose dolphin clitoris probably provides pleasure during sex, says Patricia Brennan, an evolutionary biologist at Mount Holyoke College in South Hadley, Mass.

Heterosexual and homosexual sex is common in dolphins, including femalefemale sex. "What that looks like is females stimulating each other's clitoris," with snouts, flippers or flukes, Brennan says. Females also masturbate by rubbing their clitoris against seafloor objects.

In many animals, the clitoris has gotten much less research attention than male genitalia. The first rigorous study of clitoral anatomy in humans wasn't published until 1998.

While studying the dolphin vagina, the large size of the clitoris aroused Brennan's curiosity. She and her colleagues examined the organ and looked under the wrinkled clitoral hood, an area In the waters surrounding Antarctica, Jonah's icefish create circular nests with rocky centers, where the fish can lay more than 1,000 eggs.

That device recorded video and used sound to map the seafloor.

At one location, a researcher operating the camera tow noticed that it kept encountering circular nests of Jonah's icefish (*Neopagetopsis ionah*) down below. Icefish, which are found only in Antarctic waters, have strange adaptations to the extreme cold, including clear blood full of antifreeze compounds.

"When I came down half an hour later and just saw nest after nest the whole four hours of the first dive, I thought we were onto something unusual," Purser says.

Purser and colleagues made three more surveys in the area and continued to find nests at a similar density. Perhaps one of the closest comparisons to icefish among nest-spawning fish are bluegills (*Lepomis macrochirus*), which form breeding colonies that can have hundreds of individuals, Purser says. But based on measurements showing about one icefish nest per four square meters across hundreds of kilometers of territory, the population of the Weddell Sea colony is

of enlarged erectile tissue near the vaginal entrance where contact and penile stimulation during copulation is likely.

Excising clitorises from dolphins that died of natural causes, the team found that the clitoral body is supplied by abundant large nerves at the skin surface. Dissection and CT scans also revealed structural features similar to the human clitoris. For instance, the dolphin clitoris has erectile bodies with dense layers of connective tissue, made up of collagen and elastin fiber that maintain structural integrity under pressure. The team also found encapsulated sensory nerve endings similar to those called "corpuscles of pleasure" in humans.

The findings are "striking but not surprising," says physiological ecologist Teri Orr of New Mexico State University in Las Cruces. Orr, a former postdoc in Brennan's lab, studies genitalia across species. As several orders of magnitude larger.

The icefish may sustain Weddell seals, the team says. Previous studies have shown that the seals spend a lot of time diving in waters above the colony.

Why so many icefish gather in one spot to breed is unclear. One reason may be that there's good access to plankton, a crucial food source for young fish.

Purser thinks smaller Jonah's icefish colonies may exist closer to shore, where there is less ice cover. But it's possible, that this icefish species disproportionately relies on the massive breeding colony, effectively putting all its eggs in one basket. That "would make the species extremely vulnerable" to extinction, says evolutionary biologist Thomas Desvignes of the University of Oregon in Eugene, who was not involved in the research. The colony discovery, he says, is one more argument for enacting environmental protections for the Weddell Sea, as has been done for the nearby Ross Sea.

Purser now has two seafloor cameras monitoring the site to see if nests are reused over time. "I would say [the colony] is almost a new seafloor ecosystem type," he says. "It's really surprising that it has never been seen before."

in bonobo and chimp groups, she says, dolphin group dynamics involve bonding and pleasure-seeking through sex.

However, at least two other potential hypotheses may explain the evolution of the dolphin clitoris, Orr says. The thicket of nerves supplying the clitoris may reflect its shared embryology with the male penis. During development, both arise from the same types of tissues, and the penis is also well-supplied with nerves. Additionally, although modern dolphins do not have ovulation induced by an external stimulus, perhaps clitoral stimulation played a role in stimulating ovulation in dolphin ancestors, Orr says.

With a historical and persistent gender bias in reproductive biology research, there's much to learn about female sexuality. Dolphins "might have something to tell us about ourselves," Brennan says. "We have a lot to learn from nature."

#### EARTH & ENVIRONMENT

## Some volcanic hot spots aren't so hot

Relatively cool conditions point to a shallow source of volcanism

#### **BY SID PERKINS**

Some volcanic hot spots may be fueled by molten material that originates surprisingly close to Earth's surface.

While some of the hottest spots are fed by plumes of buoyant material welling up from deep within Earth, as expected, the molten flows that drive activity at cooler hot spots result from relatively shallow geophysical processes, a study suggests.

A lot of volcanism occurs at or near the edges of the tectonic plates that make up Earth's crust. At mid-ocean ridges, which often form the boundaries between plates, hot material wells up from the mantle, the hot, thick layer between the core and crust, to create fresh crust.

More mysterious volcanic activity occurs in the middle of a tectonic plate, says Xiyuan Bao, a UCLA geophysicist. The Hawaiian Islands, the South Atlantic's Ascension Island and the South Pacific's Pitcairn Islands are a few examples of volcanoes fueled by such activity.

Scientists suspect that many sites of isolated volcanism, called hot spots, are fed by plumes of hot material rising from the deep mantle, somewhat akin to small packets of water rising to the surface in a pot of near-boiling water. A study by Bao and colleagues in the Jan. 7 *Science* finds that some hot spots are fueled by material that isn't as hot as expected, casting doubt that the volcanic activity there is driven by deep-mantle plumes. The results could help scientists figure out the processes unfolding at various sites



Volcanic activity that formed Ascension Island in the South Atlantic Ocean may have been fueled by geologic processes close to the surface.

of volcanism in the interior of plates.

Bao's team focused on 26 hot spots, using seismic data to estimate the temperature of mantle material at various depths from 260 to 600 kilometers. The hotter the material is, the slower seismic waves tend to travel through it.

The team compared the temperature estimate for each hot spot with the average temperature of mantle material welling up at mid-ocean ridges. Because plates pull apart there, there's no resistance to upwelling of hot rock from the mantle. But in the middle of a plate where there's no such seam, mantle rock must be hotter to pierce through the crust and cause volcanism. Thus, mid-ocean ridge temperatures provide a baseline against which to compare hot spot temperatures.

Temperatures at mid-ocean ridges average about 1388° Celsius. For a dozen of the hot spots studied, deep-mantle material was more than 155 degrees warmer than that — hot enough to rise to the surface, chew through the crust and create prodigious volcanic activity.

But for 10 hot spots, deep-mantle material was only 50 to 136 degrees warmer, just warm enough to rise to the surface and through crust. Four hot spots were only 36 degrees warmer than mid-ocean ridges or cooler, suggesting the material wouldn't rise fast enough to sustain buoyancy and break through the crust. Other geophysical processes closer to Earth's surface fuel the activity at these 14 coolto-middling hot spots, the team proposes.

"The evidence for mantle plumes under most volcanic islands is lacking," says geochemist Godfrey Fitton of the University of Edinburgh. An alternate source of molten material, he says, could be areas where plates collided to help create past supercontinents. In those crumpled zones, the crust would be thicker and thus help insulate against the flow of heat from the mantle. The buildup of heat in the crust could then lead to local melting of rocks that could fuel volcanism.

#### GENES & CELLS

## Genetic analysis hints at how COVID-19 messes with smell

One of the fastest tip-offs of having COVID-19 is the loss of taste or smell. Now researchers have pinpointed genetic variants that may make some infected people more likely to lose these senses.

A study of nearly 70,000 adults with COVID-19 found that people with certain genetic tweaks on chromosome 4 were 11 percent more likely to lose the ability to smell or taste than people without the tweaks, researchers report January 17 in *Nature Genetics*. The data come from people who'd had their DNA analyzed by genetic-testing company 23andMe and self-reported a case of COVID-19.

Two genes that help people smell, UGT2A1 and UGT2A2, reside in the region of chromosome 4 linked to sensory loss, epidemiologist Janie Shelton of 23andMe and colleagues found. Both genes code for enzymes that metabolize odor molecules. Studies suggest that loss of smell with COVID-19 stems from infections in smell-supporting cells called sustentacular cells. Variants near UGT2A1 and UGT2A2 could affect how the genes turn on or off, Shelton says.

The team asked about loss of smell and taste in one survey question so the study can't parse whether the variants are involved in the loss of one sense over the other. "When you lose your sense of smell, often your taste is highly diminished," Shelton says. Taste can also go away without loss of smell.

For some people, the loss of smell can last a long time. Knowing how the disease snuffs out sniffing ability could help researchers find ways to bring the sense back. – *Erin Garcia de Jesús* 

#### EARTH & ENVIRONMENT

#### Scientists have underestimated the threat of volcanic avalanches Avalanches of ash, gas and rock that

cascade downhill during volcanic eruptions may be even more dangerous than scientists had realized.

Pulses of high pressure form within these slides, called pyroclastic flows, as a result of turbulence, researchers report December 15 in *Nature Communications*. Those pressures can be far stronger than previously estimated.

Conventional hazard assessments probably drastically underestimate the destructiveness of some pyroclastic flows, says volcanologist Gert Lube of Massey University in Palmerston North, New Zealand. Assessments might suggest a flow will only burst windows, "when actually, the pressures are so strong, they knock down the walls of the building," he says.

Due to pyroclastic flows' violent nature, researchers often have to estimate pressures using computer simulations based on deposits left by past flows. For a more direct assessment, Lube and colleagues reproduced smaller versions of the flows in experiments. The team also analyzed the first measurements of pressures in natural flows, collected in 2019 when New Zealand's Whakaari volcano erupted, and flows engulfed infrasound sensors.

Pressures in the flows oscillated rhythmically, as volcanic particles clustered into cascading waves and trains of rolling eddies. These pressure pulses would successively damage obstacles like blows from a jackhammer, Lube says. The pulses sometimes smashed more than three times as hard as average estimates in conventional simulations. – *Nikk Ogasa* 

#### HUMANS & SOCIETY

Homo sapiens fossils in East Africa get pushed further back in time Fossils of the oldest known *Homo sapiens* individual in East Africa are more ancient than previously thought.

A partial *H. sapiens* skull and associated skeletal parts found in 1967 near Ethiopia's Omo River date to at least 233,000 years ago, pushing back the age of the fossils, known as Omo 1, by 36,000 years or more. An age well exceeding 200,000 years fits with recent discoveries suggesting that *H. sapiens* evolved across Africa starting about 300,000 years ago (*SN: 7/8/17 & 7/22/17, p. 6*).

A volcanic eruption about 233,000 years ago left a layer of ash atop the sediment that yielded Omo I, say volcanologist Céline Vidal of the University of Cambridge and colleagues. That ash layer



Pyroclastic flows – volcanic avalanches of gas, ash and rock – possess rhythmic, high-pressure pulses as a result of turbulence.

has a chemical fingerprint matching that of a volcanic crater 350 kilometers northeast of the fossil site. Dating of hardened ash at the volcanic crater led to the new minimum age estimate for the fossils, the scientists report January 12 in *Nature*.

Another ash layer lying near the fossilbearing sediment, but with uncertain origins, provided the previous age estimate of about 197,000 years old. – *Bruce Bower* 

#### ATOM & COSMOS

Second possible exomoon identified Some of the same researchers who found the first purported exomoon now say that they've found another. Dubbed Kepler 1708 b i, the satellite has a radius about 2.6 times that of Earth and circles a Jupiter-sized exoplanet that orbits its parent star about once every two Earth years, the team reports January 13 in *Nature Astronomy*. That sunlike star lies about 5,700 light-years from Earth.

To find this nugget, the team sorted through a database of over 4,000 exoplanets detected by NASA's Kepler space telescope. The team focused on a subset of 70 exoplanets that were likely to have moons large enough to be detected. After further screening, the team identified a strong candidate for an exomoon. Like its host planet, it caused detectable dimming of the parent star's light when moving across the face of the star.

Both proposed exomoons need to be confirmed by observations with other instruments. But fresh observations will need to wait: The new exomoon candidate won't pass in front of its star again until 2023, the team calculates. – *Sid Perkins* 





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# Military Lessons on Integration

After a 1930s U.S. government policy cemented segregation, the military pushed back By Sujata Gupta

Army veterans Amber (center) and Charles Williams and their two children live in Killeen, Texas, while Charles' teenage son visits from Waco. Killeen is considered one of the most integrated places in the United States. mber Williams and her husband bought their first house in 2008 for \$80,000 in the small military city of Killeen, Texas. "I wanted to go big and bad, but he nipped that in the bud," Williams quips.

For this Army veteran, who launched her own personal training company in 2013, buying even a modest home meant that she'd reached a new station in life, moving up from her lower-income beginnings. "We actually lived in a mobile home all of my childhood," she says.

Williams, a Black woman, first arrived at Fort Hood, the Army base near Killeen, in 2006. She returned to the base after two deployments to Iraq, and her children, now ages 11 and 13, were born there. This area, where life revolves around Fort Hood, the area's largest employer, has become home, she says.

About an hour's drive from the state capital of Austin, Killeen ranks as one of the most integrated

metropolitan areas in the country, according to a 2021 report by researchers at the University of California, Berkeley. To identify segregated pockets within a larger geographic area, the report compares the proportion of racial minorities in a smaller area, such as a neighborhood, with its larger region, such as a county.

Integration in Killeen is evident in everyday life, Williams says. Her neighbors come from many different backgrounds, and her children have had several Black teachers, even though the vast majority of U.S. public school teachers are white. Most of her friends in Killeen, also current or former military, are in interracial relationships.

Killeen is not an anomaly. The UC Berkeley researchers found that the most integrated places in the country have a strong military presence, including larger cities such as Fayetteville, N.C., and Colorado's Aurora and Colorado Springs. "The biggest players for effective integration ended up being these military towns," says social psychologist Lindsey Burnside of UC Berkeley, who worked on the report.

Integration in these places is no accident. By the late 1940s, the military was starting to realize that segregation threatened troop cohesion and efficiency, says economist Chantal Smith of Washington and Lee University in Lexington, Va.

What's more, military leaders could enforce desegregation efforts much more aggressively than leaders in civilian institutions due to the notion of rank over race, Smith says. "The military is on some level color-blind. Orders are orders. You follow the orders."

That hierarchical structure can lead to abuses within the institution, such as leaders ignoring reports of mental health problems and sexual violence. But that same structure translates to service members of all races gaining equal access to education benefits, housing, pensions and health insurance.

The body of research available today, which largely focuses on the Black-white racial divide, shows that compared with Black civilians, Black service members fare better on numerous metrics, including household income and homeownership rates.

As a result, many Black people, especially women, see enlisting in the military as one of the clearest routes to a better life. Even though Black people account for roughly 14 percent of the U.S. population, over 17 percent of active duty service members are Black. And Black women make up 26 percent of female active duty service members. Enlisting in the military for opportunity involves a trade-off, though, Williams says. She credits the institution with instilling in her a discipline and drive to get ahead in life. But she also acknowledges the loss of autonomy. In the military, she says, "your time is never really your time because you're always on Uncle Sam's clock."

#### **Baked-in segregation**

Some years before the military integrated the troops, Vince Mereday, a Black U.S. sailor who served during World War II, passed his pilot's test while stationed at the Great Lakes Naval Training Center outside Chicago. But Black service members at Great Lakes were forbidden from attending flight training. So Mereday worked as a mechanic during the war, recounts race and ethnicity scholar Richard Rothstein in his 2017 book *The Color of Law: A Forgotten History of How Our Government Segregated America*.

Discrimination against Black people persisted even after the war. At the time, real estate developer William Levitt was building his namesake Long Island, N.Y., suburb for returning veterans. Mereday's uncle received a contract to deliver drywall to the Levittown construction site. Yet the developer denied Mereday's application to buy his own home there; so instead, he bought a house in a predominantly Black suburb



To avoid jeopardizing the generous government subsidies he received to build tracts of homes on Long Island, N.Y., for veterans returning from World War II, developer William Levitt accepted applications only from white homebuyers.





This 1936 map of Philadelphia shows the "redlining" that labeled neighborhoods with Black residents as "hazardous" investments, meaning they were at high risk for home mortgage foreclosure. near Levittown, called Lakeview.

Mereday was the victim of segregationist housing practices that seeped into official government policy in the early 1930s. Vowing to lift the nation out of the Great Depression, President Franklin Roosevelt created a new federal agency called the Home Owners' Loan Corporation, or HOLC, to address the country's foreclosure crisis.

Agency appraisers traversed the country ranking neighborhoods from A to D, in increasing order of perceived foreclosure risk, to determine who could receive loans. In the resulting color-coded maps, A neighborhoods were green, B neighborhoods were blue and C neighborhoods were yellow. The presence of Black families all but guaranteed that a neighborhood would receive a D grade. Those D neighborhoods were depicted in red - hence the term "redlining," a discriminatory practice in which mortgage lenders deny home loan applications based on the racial or ethnic characteristics of applicants' neighborhoods. In 1930s St. Louis, for example, none of the city's roughly 94,000 Black residents lived outside a neighborhood that received a D grade.

"It wasn't good enough to just be a white neighborhood to get a good grade. The appraisers had to believe that there was no risk of integration," says sociologist Jacob Faber of New York University, who documented that history in 2020 in the *American Sociological Review*. "'Infiltration' was actually the term that they used."

The color-coded maps would later underpin larger federal housing programs, including loans issued through the Federal Housing Administration and the Department of Veterans Affairs.

Mereday and other Black service members were stuck. Levitt wouldn't allow Mereday to buy a home in Levittown, in part because by integrating his new development, Levitt would have lost his federal government subsidies, Rothstein writes. But because Mereday bought a home in a predominantly Black, "risky" suburb, he couldn't get a zero-down payment, low-interest VA loan.

"His experiences of discrimination in the Navy and in the housing market permanently embittered him," Rothstein writes.

#### A case study in desegregation

Had Mereday been born a generation later, his quest for a home might have ended differently. On July 26, 1948, President Harry Truman issued Executive Order 9981, which effectively mandated that the armed forces integrate. The move was, in part, politically expedient. Truman was running for re-election in a heated race against Thomas Dewey, who had a good record on civil rights issues. Truman hoped integrating the military would woo Black and other minority voters.

The scheme was well-timed. By the early 1950s, the United States was at war with North Korea and needed racial unity within the troops. By the war's end, the U.S. Army reported that 90 percent of Black soldiers were serving in integrated units.

But back home, once they stepped off base, Black service members still had to contend with local prejudices. At one base in the Deep South, for example, Black service members riding a public bus on the base had to move to the back of the vehicle once it crossed into the city. Restaurant and shop owners could refuse to serve Black service members. And local school systems placed Black service members' children in segregated schools.

The military largely followed local practices on housing. When community members and landlords objected to housing Black service members in neighborhoods close to base, commanders went along.

But by the mid-1960s, the military began prioritizing national security, and by extension, racial integration, over local concerns. "The [military's] intent was not necessarily noble. The intent was manpower readiness," says sociologist and demographer Jennifer Lundquist of the University of Massachusetts Amherst.

From 1967 to 1968, the Department of Defense implemented a program called Nondiscriminatory

Housing for Military Personnel to get U.S. landlords to rent to all service members, regardless of race. Local military leaders first surveyed off-base housing in their area to see how many landlords were already in adherence with the program. The effort revealed that about 60 percent of 25,000 rental units surveyed were open to Black and brown tenants.

When discriminatory landlords did not respond to "gentler" compliance methods, military leaders hit them with an ultimatum: Rent to all soldiers, or rent to none. With many military bases serving as the largest employer in town, landlords who refused to comply risked going out of business, Lundquist says.

The military's approach worked. By August 1968, landlords for 90 percent of the facilities surveyed had pledged, in writing, to rent to service members of all races.

#### **Black civilians**

In the civilian world, however, 1960s civil rights legislation aimed at ending discrimination in employment, education and housing — policies that, at least on paper, resembled those in the military — largely stalled. "Almost all the civil rights legislation was very weak on enforcement," says sociologist Doug Massey of Princeton University.

In housing, for example, "HOLC's practices of racial exclusion were adopted by subsequent federal programs, which were larger and more durable," Faber wrote in his 2020 report in *American Sociological Review*. "Most notable among these were the Federal Housing Administration (FHA) and the GI Bill." Between 1950 and 1960, he noted, the two "massive" programs financed a third of privately owned housing units, and played a big hand in boosting the U.S. homeownership rate from 44 percent in 1934 to 63 percent in 1972.

Consequently, many white families, which typically have easier access to home loans, have been building wealth for decades, creating a growing racial wealth divide, says Anne Price, president of the Insight Center for Community Economic Development, an organization in Oakland, Calif., dedicated to economic justice. "Wealth begets wealth."

In 2019, the median white family's net worth hovered at \$188,200, almost eight times as high as the median Black family's net worth of \$24,100, the Brookings Institution, a Washington D.C.–based nonprofit public policy organization, reported in 2020. That wealth gap links to wide racial gaps in homeownership. For example, in 2019, some

#### George Romney's radical vision

For a brief moment in history, the United States seemed like it might follow the U.S. military's path to integration. In 1968, on the heels of Martin Luther King Jr.'s assassination and subsequent protests, Congress passed the Fair Housing Act.

Although political leaders saw the act's passage as largely symbolic, the man tasked with enforcing it saw otherwise. George Romney, father of Sen. Mitt Romney of Utah, was President Richard Nixon's Housing and Urban Development secretary. In that role, Romney sought to bring Black city dwellers into the nation's white suburbs through two policies, a public one known as Operation Breakthrough and a clandestine one known as Open Communities.

The purpose of Operation Breakthrough was to build affordable housing in the suburbs — a goal that merely alluded to Romney's larger integrationist goals. Internal memos, though, reveal that Open Communities was actively integrationist. "The white suburban noose around the black in the city core is morally wrong, economically inefficient, socially destructive, and politically explosive," John C. Chapin, Romney's special assistant, wrote in a 1969 memo.

The Open Communities Task Force targeted suburbs, such as Warren, Mich., for integration. In 1970, the Detroit suburb was home to 179,260 residents, of whom 132 were Black. When Warren officials balked at building more affordable housing, Romney borrowed from the military playbook: He threatened to withhold HUD water and sewer grants. "You can try to hermetically seal Warren off from the surrounding areas if you want to, but you won't do it with federal money," Romney reportedly said.

Nixon eventually forced Romney to back down to avoid alienating his suburban voting base. The big stick approach that overhauled race relations in the military spelled Romney's downfall. He resigned in 1972.

For his radical vision, Romney "got railroaded out of the administration," says sociologist Doug Massey of Princeton University. — Sujata Gupta



George Romney (far left), shown at a 1963 anti-discrimination march, took an aggressive stance against segregation when he became U.S. Housing and Urban Development secretary in 1969. But his efforts failed and he resigned in 1972.

73 percent of white, non-Hispanic people owned their homes compared with about 42 percent of Black people.

Homeowners still receive government support not typically available to renters, such as tax breaks, Price says. "These are policies that help people maintain and build wealth. They are geared toward high-income earners, people who have homes of high value. Those people tend to be white people."

Redlining's legacy also means that homes in Black neighborhoods appreciate more slowly than homes in white neighborhoods (*SN: 5/11/19 & 5/25/19, p. 16*). Consider the trajectories of Levittown and Mereday's Lakeview neighborhood. With Levittown houses selling for at least \$350,000 nearly five years ago when Rothstein published his book, white families who bought homes there in 1948 had accrued, on average, over \$200,000 in wealth. Black families who bought in Lakeview, meanwhile, gained no more than \$45,000 during that time.

Residents in predominantly Black towns like Lakeview were also hit hard by the 2008 housing crisis. Massey has documented how mortgage brokers had previously targeted buyers in predominantly Black neighborhoods for subprime loans, which came with high interest rates and fees. That caused many more Black families to face foreclosure on their homes than white families.

Faber wondered what would have happened if that history, starting with HOLC and up to the present, had never transpired. What if the federal government had instead sought to break up the de facto segregation that characterized many U.S. neighborhoods in the 1930s by prioritizing loans for Black people?

Faber's calculations showed that in actual 2010, over a third of people in HOLC-appraised cities would have had to move for integration to occur. But in the alternate universe of Faber's model, less than a quarter of people would have had to move for that same outcome.

Similarly, in real-life 2010, almost 5 million Black people lived in cities in which almost 70 percent

Median household income in 2017 by race for veterans and non-veterans, ages 25–54

Race/ethnicity	Veterans	Non-veterans
White	\$93,800	\$88,700
Black	\$77,400	\$50,300
Hispanic	\$83,200	\$52,400
Asian	\$95,300	\$100,800

of residents would have had to move to integrate neighborhoods. Under an antiracist policy, highly segregated cities would not exist.

Public policies entrenched segregation in the United States, Faber says. But he sees an upside. "We know what we did to segregate, so we know, in a way, how to desegregate."

#### Attitude changes

By the 1980s, results of the military's experiment in integration were becoming apparent. In 1994, researchers reported in the *American Sociological Review* that military communities had the lowest levels of segregation in the country.

Since then, researchers have shown that military service seems to foster long-term changes in racial attitudes. Soldiers report that relations are better in the military than in civilian society; service members have higher rates of interracial marriage than civilians; and white and Black veterans alike live in more diverse neighborhoods than their civilian peers.

Lundquist and others attribute many veterans' increased comfort with diversity to a half-centuryold theory known as the "contact hypothesis." Formalized by Harvard University psychologist Gordon Allport in the 1950s, the hypothesis has a simple premise: Social interaction across groups can reduce prejudices.

Testing that theory in the civilian world has proved difficult, however, as Black and white people often occupy different residential, social and workplace niches. "Segregation essentially prevents that sort of contact from happening," Massey says.

The military's push to integrate has turned the institution into an ideal testing ground, Lundquist says. Service members of different races and ethnicities regularly interact — in the mess hall, in the barracks and in their neighborhoods. And now Lundquist's research and that of others suggests that those interactions persist across time.

To be sure, social contact among members of different races, and the accompanying changes in attitude, cannot completely erase racial disparities. Black service members and veterans fare better than Black civilians on multiple metrics, including homeownership rates and income, but they have yet to attain parity with white service members.

For instance, in 2017, the median income for Black non-veterans in the United States was \$50,300 compared with \$77,400 for Black veterans, according to the U.S. Census Bureau's

#### Military boost

Among whites, Blacks and Hispanics, veterans outearn non-veterans. But like non-veterans, Black and Hispanic people who served in the military have yet to reach income parity with white and Asian veterans. SOURCE: PEW RESEARCH CENTER AND 2017 AMERICAN COMMUNITY SURVEY American Community Survey. But the median income for white veterans was \$93,800.

Yet racial contact in military towns has helped lift everyone in those communities, Massey says. "That [contact] is the formula for moderating the color line." Black civilians living in military towns enjoy slightly higher incomes and homeownership rates compared with Black people living in other parts of the country, according to a 2021 report by the Urban Institute, a nonprofit economic and social policy research organization in Washington, D.C. The military is often the largest employer in these military towns and cities, thus providing good jobs to all people living in the vicinity, says Jung Hyun Choi, an expert on racial equity in housing at the Urban Institute. "Our question, of course, is: Can a private employer provide these same benefits?"

#### **Dreams expand**

Williams, who served in the military for a decade, never intended to leave. "I was supposed to go the distance," she says.

But then both she and her husband, Charles, deployed to Iraq, forcing them to leave their then 6-month-old son in the care of her mother. When their daughter was born two years later, Williams knew she couldn't endure another deployment. "If it weren't for my babies and wanting to really, really put time and effort into my kids, I would have stayed," Williams says. "I mourned my career for at least two years after getting out."

Two years later, Charles, who is also Black and who also intended to go the distance, left the Army. After years in harm's way, he had developed post-traumatic stress disorder. But Williams says he left for other reasons. With so many stints overseas, he could not pursue the education he needed to move up the ranks. "He got looked over for a promotion," she says.

That story is familiar for many Black service members. In 2020, while over 18 percent of enlistees were Black, only about 9 percent of officers were Black, the Department of Defense reports. Attendance at the prestigious military schools that pave the way to higher-ranking positions remains predominantly white, and military leaders often push Black service members toward specializations with less promotion potential, the *New York Times* reported in 2020.

After two years of searching, Charles found a job as a military contractor, with more stints overseas. He returned in January from his 12th overseas assignment, in Djibouti in eastern Africa.



For Faber, stories like that of Amber and Charles Williams illustrate the potentially steep cost of pursuing opportunity through the military. "Why can't we offer these things without the severe risk of death or trauma?" he asks.

Amber acknowledges the costs but says she has no regrets. She and Charles purchased their second home in 2010, also using a VA loan. That was the dream home at the time, Williams says, but those dreams have since grown. "Now that I live here, it's not my dream home. We are looking to buy again!" she says via text. She has also reached a level of professional success she never expected. With her personal training business going well, she launched a mobile juice company in 2021.

"I was on track to stay right there with my mom in that mobile home," Williams says. "I do feel like I've arrived. I really do. My kids are being raised differently, and we don't have to live paycheck to paycheck."

#### **Explore more**

- Stephen Menendian, Samir Gambhir and Chih-Wei Hsu. "Roots of structural racism. The 2020 Census update." University of California, Berkeley. October 11, 2021. bit.ly/structuralracism2020
- Jacob W. Faber. "We built this: Consequences of New Deal era intervention in America's racial geography." American Sociological Review. October 2020.

Amber Williams (left) and her husband, Charles (right), recognize that sacrifices come along with enlisting, such as deployments to war zones, lingering trauma and racial disparities in promotions. But those sacrifices have been worth it, Amber says, because they have given her family access to a middle-class way of life.

# Reading Our Genes

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## How the Human Genome Project revolutionized our understanding of our DNA

FEATURE

n October 1990, biologists officially embarked on one of the century's most ambitious scientific efforts: reading the 3 billion pairs of genetic subunits — the A's, T's, C's and G's — that make up the human instruction book. The project promised to blow open our understanding of basic biology, reveal relationships between the myriad forms of life on the planet and transform medicine through insights into genetic diseases and potential cures. When the project was completed in 2003, the scientists having read essentially every letter, President Bill Clinton called it a "stunning and humbling achievement" and predicted it would "revolutionize the diagnosis, prevention and treatment of most, if not all, human diseases."

Even dreaming up such an endeavor depended on decades of previous discoveries. In 1905, English biologist William Bateson, who championed the work of Austrian monk Gregor Mendel, suggested the term genetics for a new field of study focused on heredity and variation. Early the next decade, American biologist Thomas Hunt Morgan and his colleagues showed that genes are carried on chromosomes. Biochemists had been studying DNA for nearly three-quarters of a century when Oswald Avery and his team at the Rockefeller

ScienceNews 100 To celebrate our 100th anniversary, we're highlighting some of the biggest advances in science over the last century.

To see more from the series, visit the Century of Science site at www.sciencenews.org/century Institute in New York City helped establish in the 1940s that DNA is the genetic material. And perhaps most notable, and famous today, is the 1953 discovery of the double-helix structure of DNA, by James Watson and Francis Crick of the University of Cambridge and Rosalind Franklin and Maurice Wilkins of King's College London.

But when the draft of the genetic instruction book was first published, independently by an international collective of academic and government labs called the Human Genome Project and the private company Celera Genomics, led by J. Craig Venter, the text was "as striking for what we don't see as for what we do," *Science News* reported (*SN: 2/17/01, p. 100*). There were many fewer genes than expected, leaving a puzzle about what all the remaining DNA was for.

In the decades since, scientists have filled in some of that puzzle—identifying a host of genes, for example, that don't make proteins but are still essential in the body. Other researchers have searched the instruction book to find new treatments for diseases and to figure out how we're all related — not just people, but all life on planet Earth, past and present.

To explore how far our understanding of our DNA has come, *Science News* senior writer and molecular biology reporter Tina Hesman Saey talked with Eric Green, director of the National Human Genome Research Institute at the National Institutes of Health in Bethesda, Md. Green got his start in genomics in the lab of Maynard Olson at Washington University in St. Louis, a pioneer in the field. At the same time, Saey was a graduate student in molecular genetics, working down the hall. She remembers as an undergraduate student sequencing the genes of bacteria 50 to 100 chemical subunits, or bases, at a time. "My mind was completely blown by the idea that you could put together 3 billion bases." The conversation that follows, which has been edited for length and clarity, looks back on the project and ahead to all that's left to learn. — *Elizabeth Quill* 

#### **Ambitious beginnings**

**SAEY:** My first memory of the Human Genome Project was when I was an undergraduate student at the University of Nebraska in Lincoln, and I remember Walter Gilbert, who is a Nobel Prize winner, coming and talking about the project. He proposed this really audacious idea of sequencing 3 billion pairs of bases in the human genome — all of our DNA. After Gilbert's talk, I walked back to the lab with a couple of professors, and they were saying, "This can never happen. It's going to cost way too much money. There's just no way we can do this." So how did you pull it off?

**GREEN:** By the time the genome project started in October of 1990, I was working in a cutting-edge genomics lab at Washington University. We were one of the first funded groups to participate in the Human Genome Project. We had some ideas on how to start, and we had really no idea how we were going to pull it off.

It was the overwhelmingly compelling vision for why this was so important that galvanized enthusiasm among not only a group of scientists like myself, but also the funding agencies, the governments, the private funders from around the world, who said, "This seems unimaginable, like putting a person on the moon, but it seems so important. We'll figure it out." So it was one of these circumstances where you just get the right people in the right place, get them resourced, get them organized, be willing to do things differently, and then figure it out as you go.

**SAEY:** I got to witness this because I was a graduate student at Washington University, in a lab sequencing the yeast genome. Robert Waterston's lab, which received one of the first grants from the Human Genome Project, was right across the hall. They started with *C. elegans*, the roundworm genome. I remember they were starting very methodically, mapping out the genes and then sequencing each piece, marching along. But then, toward the end of the '90s, there was this shotgun sequencing revolution spearheaded by kind of a controversial figure, Craig Venter. You just shred the genome, throw it all in a sequencing machine and then put it together in the computer. Did that help a lot?

**GREEN:** There's no question it sped things up. What Craig successfully did was to determine that there were approaches that could be used where you didn't have to do piecemeal sequencing. The important nuance to point out is the only way you're able to put [the pieces] back together then was by having many mapping elements that allow you to hang pieces together and organize them. It's not like it all zipped together 3 billion letters. A lot of the meticulous mapping that had been done, painstaking mapping, helped provide organizing guideposts.

The press covered it as a race, and the press covered it as option A versus option B. And the truth resided somewhere in between. What was driving the change, of course, was technology advances. If you chart the time since the end of TINA HESMAN SAEY Molecular biology reporter, Science News





#### FEATURE | READING OUR GENES

the Human Genome Project, it's the same phenomenon. Every single time there's a technology surge, you find yourself doing things completely different than the way you used to.

**SAEY:** Technology has come a very long way from what I was doing. You can sequence thousands of bases at a time now.

**GREEN:** The other part of the story that sometimes doesn't get told: It's not even just the laboratory bench–based technologies. It's also the computational technologies. Some people don't realize that when the Human Genome Project started, there was not really a widely functional internet. I was just barely starting to use e-mail.

So here it was, we were one of the first funded groups for the Human Genome Project. We were considered state of the art. We were collaborating with an outside group generating some sequences, and the only practical way for my collaborator to get me the 300 to 400 bases of sequence was to handwrite it on a piece of paper and fax it to me. And I would analyze it by eye. It's just remarkable that that was where we were when the project started.

#### Garbage to gold mine

**SAEY:** In 2000 was the big press conference to announce the rough draft of the human genome. I was just starting my journalism career at the *St. Louis Post-Dispatch*, and reported on this. At that time, it was a big revelation that there were these big deserts in between genes, and that we didn't have nearly as many genes as we thought we were going to. Humans are such complex organisms, how could we not have many more genes than a fruit fly, or a worm? That just didn't make sense.

Eric Green (right) and his mentor, genomics pioneer Maynard Olson, were key players in the Human Genome Project. Below, the two review data to develop genome-mapping strategies slightly before the 1990 start of the project.



But now, I think, we are getting a better understanding, largely because of the way we can analyze the genome. Can you talk about how that evolution in thinking has progressed?

**GREEN:** Before the genome project started, some [people] were quite critical, and really said it was a bad idea. Some argued that it was a waste of time to sequence the genome end to end; we should just focus and sequence the genes, as if all of humans' biological richness was going to reside in the genes. Thank goodness we didn't listen to those critics. Because if we would have done the shortcut and only focused on the genes, we would have only skimmed the biological complexity of humans.

What we've come to learn is that while only 1.5 percent of the letters of the human genome directly encode for what are classically known as protein-coding genes — DNA that gets made into RNA, which gets made into protein — there's a much larger fraction of the human genome that is biologically important and evolutionarily conserved. It's widened our definition of a gene, because we now know that sometimes DNA may make RNA, and RNA may go off and do all sorts of biological things.

Then there's a whole set of sequences that are far more plentiful than gene sequences, that are really doing all the choreography in our genomes in terms of determining when, where and how much genes get turned on, in what cells and what tissues, at what developmental stages, under what conditions, and so on and so forth.

It pushed us to think about all the other biological functions in DNA outside the genes. And as you accurately point out, we don't really have a rulebook for that. And thank goodness the computer technology is helping us because the human eye would just fail miserably at figuring this out. And so as much as anything, computational biology, bioinformatics, data science are the dominant research tools to help bring clarity as to how noncoding sequences in the human genome function. And how they do that in a very carefully crafted choreography with the genes.

**SAEY:** Well, I'm glad you brought up those sequences, because those are some of my favorites. I'm a huge fan of noncoding RNAs [the RNAs that don't go on to make proteins]. There are so many of them, and such a huge variety of them. And they work in so many important ways (*SN*: 4/13/19, *p. 22*).

I don't think that 20 years ago we could have conceived that RNAs that didn't make proteins would actually be important for something. The genes those RNAs were copied from were considered broken genes or pseudogenes. They were junk.

**GREEN:** Or sloppy transcription; that our enzymes are just going off and making a bunch of RNA because they don't know how to control themselves. But, no. And I like your point about 20 years ago, we couldn't imagine. I would propose that 20 years from now, we might look back at this conversation and say, "Oh, my goodness, think about all these other ways that



U.S. President Bill Clinton (center) stands with J. Craig Venter of Celera Genomics (left) and Francis Collins of the NIH (right) in June 2000 to announce the completion of the first draft of the human genome.

the genome functions." There's no reason to think we have our hands around it all in terms of all the biological complexity of DNA; I'm quite sure we don't.

**SAEY**: And even when you find a protein-coding gene, you're not just making one protein. You're making, on average, seven or eight different versions of this protein from the same gene. After RNA gets copied from DNA, you can mix and match the little parts of a gene to make completely new proteins. And then you can tack on all of these other little chemical

groups to change the way things work.

**GREEN**: When I was getting my Ph.D. at Washington University in the 1980s, I didn't work on DNA, I didn't work on molecular biology, I didn't work on RNA. I was working on a set of proteins, studying how they had sugar molecules added to them after they were made, and how, depending upon what tissue they were made in, they got different structures of sugar molecules attached. So just as you point out, you start off with one gene, and you can end up with multiple RNAs that lead to multiple different proteins. And each of those proteins

could have different modifications depending on what tissue, what conditions, what development stage, et cetera. This is the incredible amplification of complexity. It's not in our gene number. We have a long way to go to fully understanding all this.

**SAEY:** Another thing that really surprises people is how much of our genome is made of extinct viruses and transposons — transposons being these jumping genes that still hop around in our genome. Those transposons can occasionally cause problems, but we also got a lot of innovations from them, including the human placenta, and maybe some things about the way our brain works. So, we're not even completely human. If you want to view it that way, we're a lot virus.

**GREEN:** Right. We're a lot virus. We're also not all *Homo sapiens*. Many, many people carry Neandertal bits from a time when Neandertals and *Homo sapiens* coexisted, and actually interbred (*SN: 5/8/21 & 5/22/21, p. 7*). But not everybody in the world has that, which is also interesting. One of the aspects of genomics is that it not only has taught us and given us the biological instruction book, it's also given us a fascinating record of evolution. We can use it to learn lots of things about our evolution, about human migrations, about aspects of humans on this globe.

#### **Focus on diversity**

**SAEY:** Most people who are interacting with DNA and with the human genome these days do it through ancestry testing and consumer DNA testing. So you can identify the part of the world that people's DNA came from. And that gets into a lot of discussion about race, and whether race has a biological basis, and what that might mean for medicine.

There's been a lot of criticism lately of genetics and genomics, because it's based a lot on the DNA of people of European ancestry — white people like you and me. But there's a huge amount of genetic diversity in the world among humans, and especially in Africa, where humans got started. So what are we doing about getting a handle on the vast array of diversity that humans have?



Number of protein-coding genes in a recent analysis of a human genome

Total number of genes, including those that make RNAs but not proteins, in the same analysis

SOURCE: A.V. ZIMIN ET AL/GENETICS 2021

**GREEN:** There's no question that the successes in genomics that we've been discussing are worth talking about and worth showcasing. At the same time, as a field, we have not been perfect. One of the things that we just have to admit that we've really not been as successful on is making sure we've captured enough of the diversity of the human population with respect to the samples that we've used for doing genetic and genomic studies. We have got to fix this problem. It's a very high priority.

I really want to emphasize, it's not even just that it's the socially right thing to do, that everybody should have information

about their genomes. This is very important medically. If the only populations we have a lot of genomic data on are people of European descent, we limit our ability to move genomic analyses and eventually genomic medicine into populations that are not of European descent. And so there's a high priority through a number of efforts around the world, including in the U.S., to work hard to capture much more diversity of the world's populations in all studies that we do.

**SAEY:** There's been a lot of talk about racialized medicine, where you might have a person come in who is African American, and then you would say, "Oh, well, we should consider this to be the genome that we look at." Is that a

#### FEATURE | READING OUR GENES

good approach to take? Or do you think it should be broader somehow?

**GREEN:** The truth is, of course, there are certain diseases that tend to cluster in certain populations of common ancestry. And many times those are represented by racial groups.

But racial grouping is really a social construct that has numerous imperfections. And so on the one hand, you can't totally ignore some correlations that exist with certain diseases or certain responses to medications in certain groups. But it's a very blunt tool to use. And we could do better. The way we could do this better is to track much more accurately to specific genomic features, as opposed to certain racial characteristics. So I think what we really want to pay attention to, and we will be doing this increasingly, is thinking about better ways of grouping and stratifying individuals and populations.

**SAEY:** I wanted to touch too on what we mean when we say genetic diversity. For the most part I think people are familiar with what scientists call SNPs, single nucleotide polymorphisms, and what other people might refer to as mutations. But there are lots of other ways that you can have diversity in the genome: You can be missing entire genes or entire chunks of chromosomes or you can have duplications of certain genes. Are we now able to look at that type of diversity as well? And do we know if that's important?

**GREEN:** There's no question that all forms of genomic diversity — genomic variation is probably the word I would use — are not only biologically relevant, they're proving to be medically relevant. Now, we don't have a complete inventory of which ones are more relevant than others. But we already know of many examples where medically relevant variations in our genome can be a single letter, a string of letters, it could mean having extra letters or extra segments, or missing segments. It could be a rearrangement of segments. Every one of those [types of variations] are already known to be important in human disease, and eventually will be important for diagnostic medicine and the implementation of genomic medicine.

**SAEY:** Do you envision a time when we will be able to study and interpret these bigger changes?

**GREEN:** I absolutely envision a time where people will get their complete genome sequenced end to end as part of their medical care, and maybe even at birth. I don't think we're there yet. But I truly believe that we will want that information as part of medical management. And I fully believe that technologies will become available and will be inexpensive enough to make it worthwhile. But those predictions are going to have to be based on evidence that indeed that's feasible and valuable. **Diversity missed** Genome-wide association studies can uncover common genetic variants that might, for example, help explain an individual's susceptibility to illness. As of January, participants in these studies were overwhelmingly European, leaving other groups underrepresented. SOURCE: GWASDIVERSITYMONITOR.COM



#### What's next?

**SAEY:** So where do we go from here? What does the National Human Genome Research Institute do now that researchers have generated end-to-end sequences of every human chromosome?

**GREEN**: We recently finished a two-and-a-half-year strategic planning process to ask that very question for this coming decade. It was actually an overwhelming exercise because there were so many good ideas. We published these in *Nature* — our 2020 strategic vision. Some of it [is] applications of genomics to medicine. Of course, everybody's going to be excited about that. But there are many other forefronts of genomics that are just as exciting.

We still don't have the perfect technologies that we can deploy anywhere in the world in any health setting, any medical study, that will get us end-to-end sequencing. We need better and cheaper technologies for letting us read human genome sequences inexpensively in clinical settings. We need complete end-to-end interpretation of every base of the human genome. We need to know not just about the genes, we need to know about all these noncoding regions. We need to understand every human variant that we can find in the world population. And we need to know: Is that variant biologically silent? Is it biologically relevant? Is it medically relevant? If it's medically relevant, what's the action that should be taken? That starts to point us to understanding the genomic basis of disease and also to think about how can we use information about genomic variation in the practice of medicine.

Also, we will continue to think about the implications of these genomic advances to society. How are we going to make

sure people understand this? How are we going to make sure things are applied equitably? How are we going to make sure it doesn't exacerbate inequities in our society? How are we going to deal with a whole host of issues related to privacy?

**SAEY:** I'm glad that you brought up equity and privacy, because those are some of the things that people are most concerned about right now. There are a lot of historically marginalized people who don't want any part of genetic research because of the way their groups have been treated in the past. There's been this history of colonialism. These groups say, if we're going to do genetics on our people, then it should be our people doing it for us. What is NHGRI doing to build capacity in these communities so that they can do their own research and, maybe, if they decide they want to, share that with other people?

**GREEN:** I completely agree with the notion that if genomics is going to be a successful field, especially as we move this into medicine, we have got to make sure that we engage people from all different communities, all definitions of diversity, and make sure they benefit from it. We absolutely emphasize this point repeatedly in our 2020 strategic vision, so much so that the very first thing we did in 2021 was to release what we call an action agenda for enhancing the diversity of the genomics workforce.

Another experience we've had at NIH that I think is very illustrative of this: We recognized that we wanted African scientists to get more involved in doing genomics. And through a program called H3Africa, the Human Heredity and Health in Africa program, that the NIH and the Wellcome Trust funded, the philosophical mantra is to empower African scientists to do all the studies and build capacity there. It's been a success by almost any metric. But it's exactly what you said: We want them to do the studies, we want them to engage with their local communities. We'll never build the trust if we just come in and say, "We're going to do all of this."

**SAEY:** In terms of privacy, you've said a couple of times that you could have somebody's genome completely sequenced, and then their doctor can use it. But don't we get into a situation that could be like the movie *Gattaca*? Some people could be discriminated against if they don't have their genetic flaws fixed? Are you somehow creating a class of lesser people and more perfect people who don't have the genetic flaws that everybody else has?

**GREEN:** You just laid out several major ethical dilemmas, and they're all valid, and we could spend hours talking about each of them. What I would say about our field is, we've recognized that everything we are doing is a two-edged sword. On the one edge of that sword are these incredible opportunities for improving the practice of medicine. On the other edge of that sword, as with many technologies, it could be used in ways that would be societally unacceptable. It's a reason why the field has from the beginning always embraced and invested in ethical, legal and social implications research, or ELSI research, which has attempted to anticipate these concerns and try to provide an evidence base to build policies, and in some cases, laws.

We do have in the United States a major act called the Genetic Information Nondiscrimination Act, which offers some protection against genetic discrimination. We have laws and policies that protect people's medical information.

We should recognize that genomics is just part of a bigger set of societal issues, as more and more intimate information about us is electronically available. Trust me, we can learn a lot about you if we just reviewed your Visa card purchases. We as a society have to recognize that, yes, genomic information has some unique attributes, but it's not totally exceptional. We need to be part of a broader framework for protecting people so that we can benefit from these incredible opportunities.

We just need to make sure we don't get too far out over our skis. Just because we can do something, doesn't mean we should. We need to think about all the consequences. We should be constantly understanding what will society tolerate, what do people not want. We have some things that are going to be completely unacceptable, like doing genetic editing in unborn children. At this stage, we simply don't think that's a smart thing to do, we're not ready to do it, the scientific community has condemned doing it (*SN*: 12/22/18 & 1/5/19, p. 20).

**SAEY:** I do want to circle back, because when we were talking about these noncoding sequences, a lot of them help control how genes are used. That may not be so obvious if you just get this string of somebody's DNA letters. Can you tell from that

Convicted serial murderer and rapist Joseph James DeAngelo, shown at his 2018 arraignment, stayed under the radar for decades until he was tracked via DNA traced through a consumer genetic database.





In 2013, protesters at the U.S. Supreme Court called for a ban on human gene patenting, questioning who should own a person's genetic information.

how those genes will be used? And how those things will be put together? Or is that something you cannot tell by looking at DNA?

**GREEN:** There's no question that sometimes when you talk about genomics, and you talk about genetics, and you focus on the genes — you sometimes see the tree and you lose track of the forest. The forest is medical complexity and biological complexity. And for most things about ourselves, how tall we are, what we look like, and common diseases — hypertension, diabetes, Alzheimer's, autism, et cetera — things are much more complicated than looking even for one gene. It's multiple genes. And it's almost always a greater choreography with our lifestyle, and our social experiences, and our exposures and everything from diet to exercise. There's a lot more to health and disease than just our genes.

The grand challenge in many ways for the coming decade or two is doing these very large-scale studies where we have as much data as possible, not just genomic data, but lifestyle data and electronic health record data, and environmental data and physiological data. There are absolutely going to be patterns. And we've just got to find those patterns.

**SAEY:** We're almost out of time. It's been wonderful talking with you. Did we miss anything?

**GREEN:** We missed all sorts of wonderful things, but you can only spend so much time walking down memory lane.

What I would say in closing are two things people need to remember: First of all, how incredibly exciting this field is, and how incredibly eager we are to build our tent with more and more people from all different disciplines. And we also want people of all different populations and ancestral groups from all parts of the world. It's going to be so important to do that.

The reason we want all these people involved is, we just touched on so many things that we still don't understand. We need creativity. And we don't have a playbook. Just like those days where we were bewildered of how we were going to get the Human Genome Project really done, I don't really know how we're going to get complete end-to-end understanding of the human genome. But I know if we get creative people working on it, we'll make incredible progress.

#### **Explore more**

- Eric D. Green *et al.* "Strategic vision for improving human health at the forefront of genomics." *Nature.* October 28, 2020.
- "Building a diverse genomics workforce: an NHGRI action agenda." January 2021. bit.ly/NHGRIdiverseworkforce

### **Essential voices**

To read three more perspectives on progress in genetics, visit www.sciencenews.org/century.

**Geneticist Tshaka Cunningham** says precision medicine will only meet its promise when vastly more Black and Latino people feel safe participating in genomics studies.

**Pediatrician Erica Esrick** is testing a possible gene therapy for sickle cell disease. The painful, life-threatening disorder affects millions of people around the world.

**Philosopher of science Yafeng Shan** looks back at how the study of Mendelian genetics as we know it today emerged from a muddle of ideas at the turn of the 20th century.



**Origin** Jennifer Raff TWELVE, \$30

## The conflicted science of the first Americans

Scientific understanding of the peopling of the Americas is as unsettled as the Western Hemisphere once was. Skeletal remains, cultural artifacts such as stone tools and, increasingly, microscopic pieces of ancient DNA have sparked heated debates about which of several origin stories best explains available

evidence. Additional conflict stems from a tragic scientific legacy of ignoring and exploiting Indigenous groups whose ancestries are on the line.

Anthropologist and geneticist Jennifer Raff offers her take on the state of this fascinating and turbulent research field in *Origin: A Genetic History of the Americas*.

Raff wants to tell the most accurate, if still incomplete, story of how humans settled the Americas by integrating research on ancient and modern DNA with archaeological finds. She refers to people who inhabited the Western Hemisphere before Europeans arrived as First Peoples, a term favored by some of her Indigenous colleagues.

Most researchers think that ancestors of the First Peoples lived in Siberia and East Asia 20,000 years ago or more during the Ice Age, Raff explains. A consensus view holds that those groups eventually crossed a now-submerged expanse of land — the Bering Land Bridge — that connected northeastern Asia and North America. Analyses of ancient human DNA indicate that these migrants gave rise to populations that lived south of an ice sheet that ran across northern North America from around 80,000 to 11,000 years ago. But much remains unexplained.

Raff delves into several competing models of how, when and where people first made inroads into the Americas. One approach holds that Ice Age Siberians, known from archaeological finds, reached North America between 16,000 and 14,000 years ago and, within a few millennia, journeyed south across the continent through a gap in the melting ice sheet. Those settlers probably founded the Clovis culture, known for its distinctive stone points (*SN*: 1/15/22, p. 22).

Another view contends that people came to the Americas much earlier, 30,000 years ago or more. A minority of researchers in this camp contends that settlers may have even reached what's now southern California by 130,000 years ago (*SN: 5/27/17, p. 7*).

But archaeological and genetic evidence best fits a third model, Raff writes. In this scenario, First Peoples reached the Americas as early as 18,000 years ago and perhaps over 20,000 years ago. These folks — including groups that were not predecessors of Clovis people — probably traveled by boat or canoe along North America's west coast, arriving in South America no later than about 14,000 years ago (*SN*: 12/26/15, p. 10).



A new book explores what genetics and archaeology, including stone tools such as these Clovis spearpoints, reveal about how people settled the Americas tens of thousands of years ago.

Raff articulates scientific arguments for these settlement scenarios in clear, nontechnical language. But her narrative revs up when she describes how geneticists, with some admirable exceptions, have treated Indigenous groups as afterthoughts or as passive DNA donors.

One example concerns a roughly 9,000-year-old skeleton found in Washington state in 1996, dubbed Kennewick Man or the Ancient One. That find sparked a legal battle between scientists who wanted to study the man's remains and local tribes intent on reburying their ancestor. The scientists won. Years later, geneticists who consulted with one tribe in the dispute worked out an agreement to sample the tribe's DNA for comparison with the Ancient One – and demonstrated an ancestral connection – before his bones were interred by the tribe (*SN: 7/25/15, p. 6*).

Many Native American groups, especially in North America, nurse bad memories of genetic researchers who misled them about study goals or never met with them to discuss DNA results at odds with tribal oral histories, Raff writes. As a result, Indigenous communities today often refuse to participate in genetic studies. Only a commitment by researchers to collaborate with those groups will resolve this standoff, she argues, as belatedly happened with the Ancient One.

Raff also provides a glimpse of how she came to study ancient DNA. A lifelong love of exploring caves, starting as a child in a caving club, imbued Raff with a respect for extensive preparation and intense focus in the moment. Those traits proved essential for conducting the many exacting lab procedures she outlines for coaxing DNA out of bone samples.

After mentioning that a few large, well-funded labs dominate ancient DNA research, Raff leaves unexplored the implications of that concentration of resources for studying ancient human migrations. But her book gives a balanced view of what's known about the First Peoples and how scientists can cooperate with their modern-day descendants. *— Bruce Bower* 

## SOCIETY UPDATE

## ScienceNews for Students

*Science News for Students* is an award-winning, free online magazine that reports daily on research and new developments across scientific disciplines for inquiring minds of every age — from middle school on up.



# What can 'silent earthquakes' teach us about the next Big One?

On February 16, 1861, a massive earthquake struck the Indonesian island of Sumatra, causing damage (aftermath of a 2005 Indonesian quake shown). It also triggered a tsunami that claimed thousands of lives. A quake that preceded it started in 1829—and didn't stop for 32 years! Yet no one felt a single shake. Such "slow-slip events" weren't even confirmed to exist until about 20 years ago. But we now "love" them, says geoscientist Rishav Mallick of Nanyang Technological University in Singapore. "They give you all of the excitement of earthquakes, just in slow motion." By investigating them, scientists hope to better understand regular quakes—and possibly how to predict them. — JoAnna Wendel

Read more: www.sciencenewsforstudents.org/silent-earthquakes

# A new way to make plastics could keep them from littering the seas

Most ocean plastics, like those shown here, would take centuries to fully degrade. That's one reason plastics now make up 80 percent of ocean trash. But a new type of polylactide, or PLA—a popular plastic made out of corn and potato starch—may change that. Like most plastics, its building blocks are linked into a chain. Scientists in the Netherlands have just tweaked some of those links to make them water-soluble and therefore easier to break down in water. Weakening 3 percent of the links caused PLA to break down after about two years in seawater. With 15 percent weakened, that breakdown time dropped to just two weeks. — *Katie Grace Carpenter* 

Read more: www.sciencenewsforstudents.org/sea-plastics





# Rewilding returns lost species to strengthen ecosystems

In March 2020, a group of conservationists in Australia fenced an area of hilly eucalyptus forest, removing nonnative foxes and feral cats. Then the team released some Tasmanian devils (one shown), the world's largest carnivorous marsupials. These became the first devils in the wilds of mainland Australia in 3,000 years. Such reintroductions are known as rewilding, and it can help restore ecosystems in which native species have disappeared due to hunting or the presence of invasive species. Rewilding can "give space for nature to do its job," explains Henrique Pereira, a biodiversity conservation researcher at the German Center for Integrative Biodiversity Research in Leipzig. The idea is to step back, he says, and "let nature do some work for us." — *Alison Pearce Stevens* 

Read more: www.sciencenewsforstudents.org/rewilding



#### FEEDBACK



DECEMBER 18, 2021 & JANUARY 1, 2022

### You asked for it

A new mathematical equation describes bird eggs of all shapes found in nature, and it could have applications in conservation and agricultural research, **Rachel Crowell** reported in "Elusive equation describes all bird eggs" (*SN*: 12/4/21, p. 11). Several readers have asked to see the eggcellent equation, shown below in its full glory.



#### **B** = Egg maximum breadth

L = Egg length

**w** = The distance between two vertical axes corresponding to the maximum breadth and the midpoint of the egg's length

 $D_{U4} = Egg$  diameter at the point that's a quarter of the egg length away from the egg's pointed end

 $\mathbf{x}$  = A number of points between -L/2 and L/2

#### Join the conversation

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#### **Fine feather**

A filament of cold, dense gas named the Gangotri wave may bridge two spiral arms near the Milky Way's center, **Lisa Grossman** reported in "Scientists find the Milky Way's first known 'feather'" (SN: 12/18/21 & 1/1/22, p. 4). Reader **Doug Holcomb** asked how this newfound "feather" differs from a galactic spur.

The language describing the different limbs of the Milky Way can get fuzzy, **Grossman** says. In general, our galaxy has four primary spiral arms emanating from its center, and an unknown number of smaller arms. A spur tends to be an offshoot of an arm, but the line between spur and arm is not so strict.

"The main difference between the Gangotri wave and other galactic tendrils is that Gangotri runs perpendicular to the larger arms of the galaxy, and crosses two of them," **Grossman** says. "That crossing of the two arms is unique, although researchers expect that there are probably more of them throughout the Milky Way that have yet to be discovered."

Reader **Jasmine Melvin** wondered whether the Gangotri wave has stars.

"Many regions within the wave are sites of active star formation," says astrophysicist **Veena V.S.** of the Max Planck Institute for Radio Astronomy in Germany. Future studies are needed to characterize the total number of stars within the structure, she says.

#### **Carbon curiosity**

Massive stars with an orbiting partner star shed on average about twice as much carbon as loner stars do, **Ken Croswell** reported in "How stars turn into carbon factories," (SN: 12/18/21 & 1/1/22, p. 12). When a massive star with a partner explodes, its carbon is cast into space, **Croswell** reported. On the other hand, a single star's core would have destroyed much of its carbon before such an explosion. Reader **Bill Camenga** wanted to know what becomes of the carbon in single stars. "The carbon doesn't just vanish," **Croswell** says. During a single star's life, most of its carbon gets transformed into oxygen. When the star explodes, that oxygen is cast into space, helping make oxygen the third most abundant element in the universe after hydrogen and helium. The exact nuclear reaction, he says, is carbon-12 + helium-4  $\rightarrow$  oxygen-16 + energy.

#### X-ray! X-ray! Read all about it!

In 1971, the first X-ray CT scan of a patient provided an unprecedented image of the human brain. Fifty years later, CT scans are still saving lives and helping researchers better understand the world around us, **Emily Conover** reported in "Celebrating 50 years of CT scans" (SN: 12/18/21 & 1/1/22, p. 44). Several readers wondered whether radiation from CT scans should be a concern for those receiving them.

Scientists have continually improved CT technology over the years, not only making it faster and higher resolution, but also decreasing the amount of radiation that people receive, **Conover** says. Although CT scans typically expose patients to more radiation than standard X-ray imaging, the amount of radiation from one scan is still relatively small. Depending on the type of CT scan, the radiation received may be less than the average background radiation a person gets from various sources in the environment over a year, she says.

There is still debate among scientists about the potential health effects of such low doses of radiation, **Conover** says. When a doctor orders a CT scan, they typically will have determined that the benefit to the patient outweighs the small risk.

#### Correction

In "Pointed takedown of the mammoth hunters" (*SN*: 1/15/22, p. 22), archaeologist Vance Holliday of the University of Arizona in Tucson, not Vance Haynes, weighed in on archaeologist Metin Eren's hypothesis that ancient Clovis points were not used for hunting the tusked beasts.



### How these tiny beetles are such superb fliers

Featherwing beetles are some of the world's smallest flying insects. Yet they can rocket along with the speed of much larger insects. Now, scientists have figured out how the beetles do it.

A wide wing stroke combined with lightweight, bristled wings allows the beetles to efficiently propel themselves through the air, researchers report January 19 in *Nature*.

Some species of featherwing beetles are so tiny that two set end to end would reach slightly more than a credit card's thickness. At such small sizes, the air feels viscous, and air friction, or drag, becomes a serious obstacle to flight. But previous research from entomologist Alexey Polilov of Lomonosov Moscow State University and colleagues showed that the insects can fly at speeds comparable to those of beetles three times as long.

Polilov and his team investigated this flying prowess further, studying one of the smallest featherwing beetles, *Paratuposa placentis* (shown above in a microscope image), using high-speed video and computer simulations.

The beetle's style of beating its wings is unlike anything previously described, the team found. The wings make a wide, figure eight pattern, clapping together on both the upstroke and downstroke to reduce drag (shown at right in the 3-D computer reconstructions of a wing stroke). This wide motion gives the beetle extra power to push through the air.

Crucially, the beetle's wings are made of thin bristles. Because of the air friction at these small sizes, those bristles



allow the wings to have the flapping power of wings made of membranes, like those of a housefly, but for a lot less mass.

"The bristled wing rows almost as well [as membranous wings] without letting much air through," Polilov says. Video recordings of some other featherwing beetles reveal a similar flying style.

The beetles' ancestors were larger than their modern kin. So the new findings give insights into how insects can retain important athletic abilities as they scale down in size. -Jake Buehler



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