Quest for a Coronavirus Vaccine | Busy Galaxy Burns Out

ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ MARCH 14, 2020

A Measure of Race in America

Can the U.S. census reflect the country's reality?

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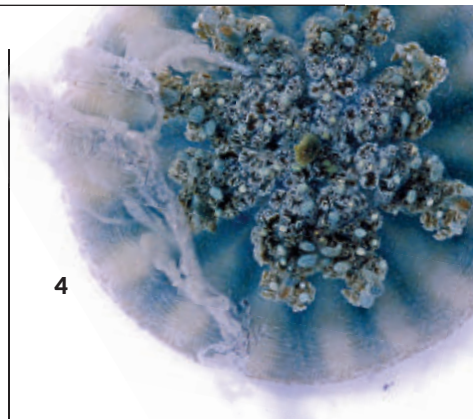

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Departments

COVER An accurate sense of racial diversity is hard to achieve with current U.S. census questions. *Delphine Lee*

CLOCKWISE FROM TOP: DELPHINE LEE; ALLEN COLLINS, C. AMES; LANOLAN/ISTOCK/GETTY IMAGES PLUS

When data points have their own opinions

In this issue, we dive into the science of demography, the study of human populations, through the lens of the U.S. census. An accurate count of the American population was considered so essential by the Founding Fathers that they enshrined the once-a-decade enumeration into the Constitution. But arriving at an accurate count has proven to be a challenge.

Births, deaths and migration drive population change, and to understand the fabric of a population, demographers often consider age, sex, family and households, as well as education, language, employment, income, wealth, race and ethnicity.

Demographic data are used to identify economic and social problems and develop solutions to address those problems. The federal government relies on census data to allocate billions in federal aid each year. Industries also use the results to identify trends and develop new markets. Local governments determine where they'll need new schools or fire stations. Scientists in many fields turn to the data for their own research.

So getting numbers right matters. But the question of people's race or ethnicity has bedeviled the census from the start, with demographic data often ignored or manipulated to serve political ends, freelance writer Betsy Ladyzhets reports (Page 22).

In 1787, the Constitutional Convention battled over how the census data should be used to allocate seats in the House of Representatives; Southern states argued for inclusion of enslaved people, while Northern states argued against that, presumably in an effort to limit the slaveholding states' power in Congress. South and North compromised on using three-fifths of states' enslaved populations in apportioning congressional seats and setting federal tax rates. And when Western states entered the Union in the mid-1800s, they argued for the inclusion of Native Americans in the census count to boost their own congressional representation.

The questions go beyond who gets counted, to how people are categorized. In the 18th and 19th centuries, census enumerators were tasked with knocking on doors and making their own guesses as to a person's race, a decidedly unscientific process. The rules later changed to allow people to report race or ethnicity themselves, but that hasn't brought the clarity one might expect, as social sciences writer Sujata Gupta reports (Page 16). Researchers have found that two people who appear to be racially very similar can define themselves very differently, depending on their nationality and culture.

And to add even more complexity, the soaring popularity of genetic ancestry tests has prompted a surprising number of people to change their answer to the question: "What is your race?"

This month, people across the United States will start getting invitations to complete the 2020 census. Researchers say they wish it included more nuanced ways to capture both how people see themselves and how they're seen by the outside world — but that's a challenge for the next enumeration.

— Nancy Shute, Editor in Chief

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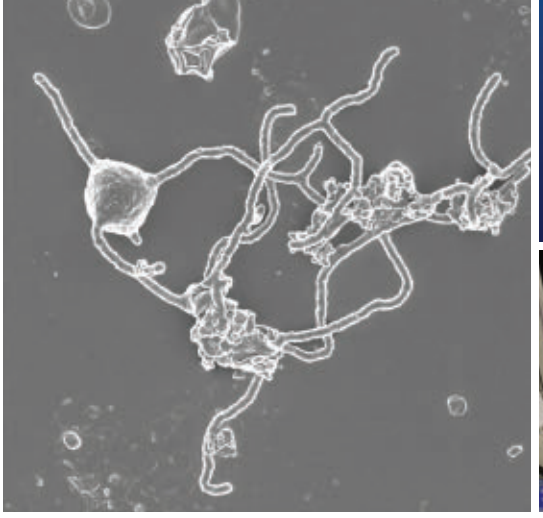
Excerpt from the March 21, 1970 issue of *Science News*

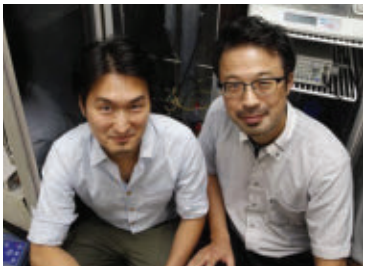
50 YEARS AGO

Studying a killer

In January 1969 an unknown virus was isolated for the first time from the sera of two nurses, who died.... The infection, being called Lassa fever, involved almost all the body's organs.... Doctors so far suspect that the disease was transmitted by an animal, but what animal is not known. It is also believed that the patients can acquire the infection from one another, but only through more than casual contact.

UPDATE: Named for the Nigerian village where cases first appeared, the Lassa virus causes hemorrhagic fever and kills about 5,000 of the hundreds of thousands of people infected each year in West Africa. The virus, spread by the Natal multimammate rat (*Mastomys natalensis*), can be transmitted through human body fluids. The World Health Organization considers the creation of a vaccine a high priority. Of nearly 30 vaccines in development, only one has been tested in people. One clinical trial of that vaccine's safety and efficacy began in the United States in May 2019, and another trial is set for Liberia, Nigeria and Ghana this month.





Researchers grew an archaean (left) from deep-sea mud collected by the research vessel *Shinkai 6500* (top right). Team members Masaru Nobu (left, at bottom right) and Hiroyuki Imachi are pictured.

THE SCIENCE LIFE

A first look at a microbe with clues to complex life

Squeezed into a submarine 2,500 meters undersea, Hiroyuki Imachi scanned Japan's Nankai Trough for signs of life. Spotting clams clustered on a white microbial mat, the microbiologist guided the sub's robotic arm to dig out a core of deep-sea muck.

It would take 12 more years to isolate a microbe from an ancient line of Archaea, a domain of life superficially similar to bacteria. "Patience is very important in doing successful science," says Imachi, of the Japan Agency for Marine-Earth Science and Technology in Yokosuka.

The feat — described in the Jan. 23 *Nature* — could help biologists reconstruct life's leap from bacteria-like organisms to complex eukaryotes, the vast group that includes everything from fungi to humans.

Many scientists think the evolution of complex cells began about 2 billion years ago, with an archaean gobbling up a bacterium. Instead of becoming dinner, the bacterium evolved into a mitochondrion, an energy-producing cellular structure.

Scientists have been searching for clues about this ancestor of eukaryotes in extreme environments like Nankai Trough, a hotbed of understudied microbes living off methane bubbling from tectonic faults. Genetic sequencing of dredged mud gives glimpses of microbes adapted to the deep. But growing the microbes in the lab to study how they look and behave is tricky; they won't grow on a petri dish.

Inspired by a sewage treatment plant's bioreactor, Imachi's team re-created a methane seep by pumping the gas into a chamber stacked with sponges mimicking the porous deep-sea sediment. Artificial seawater kept the sponges saturated. The team watered down mud from the core, sopped up the slurry with the sponges, stacked them in the reactor — and waited.

After a few years, the microbial community stabilized. Samples from the reactor were placed in 200 bottles filled with different energy sources and antibiotics to kill bacteria and allow archaeans to grow. In 2012, the team detected an archaean new to science, dubbed MK-D1, in low numbers amid multitudes of other microbes. Months of efforts to isolate and grow the archaean failed — or so the researchers thought. MK-D1 was growing, just more slowly than any other single-celled microbe ever grown in a lab. *E. coli*, for instance, replicate in 20 minutes. MK-D1 can take three weeks.

In 2015, other scientists reported a new group called Asgard archaea in genetic material dredged from an arctic hydrothermal vent. DNA evidence confirmed that Imachi's team had grown its own Asgard.

In isolating MK-D1 in 2018, the team became the first to see a living Asgard under a microscope. The neat, tiny spheres seemed unlikely to be the sort of thing that may have begotten complexity. But the microbes eventually grew tentacle-like protrusions, prompting the team to propose a model for how tentacles in eukaryotes' ancestors might have ensnared microbes.

The team has now given MK-D1 a proper name, *Prometheoarchaeum syntrophicum*, after Prometheus, the Greek god credited with introducing fire to humans. — *Jonathan Lambert*

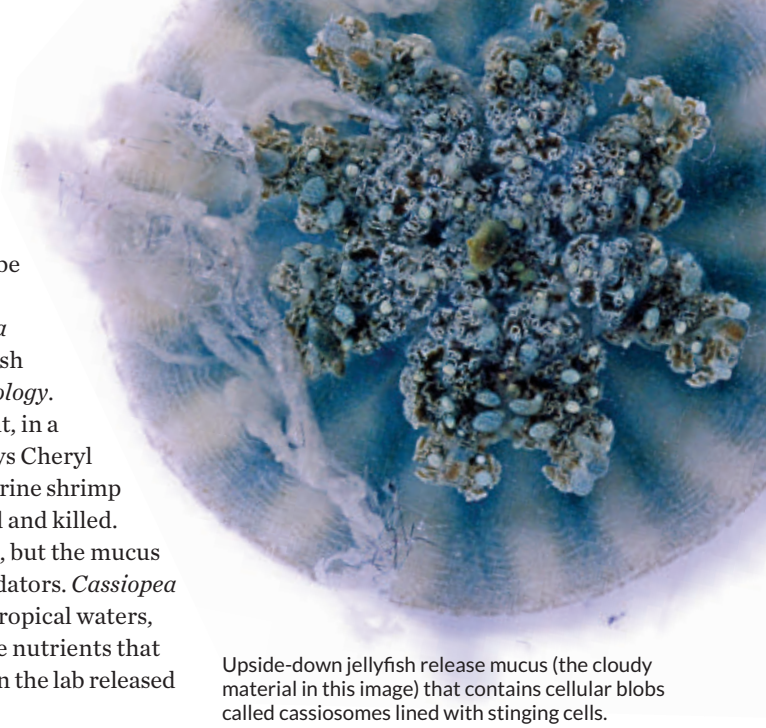
MYSTERY SOLVED

Jellyfish snot stings swimmers

Swimmers who feel "stinging water" near mangrove forests may be getting zapped by jellyfish snot.

A species of upside-down jellyfish called *Cassiopea xamachana* releases mucus filled with stinging cells typically found on jellyfish tentacles, researchers report February 13 in *Communications Biology*. The stinging cells cover tiny mobile blobs called cassiosomes that, in a lab dish, "zoom around like a Roomba zapping brine shrimp," says Cheryl Ames, a marine biologist at Tohoku University in Sendai, Japan. Brine shrimp that came into contact with a cassiosome were quickly paralyzed and killed.

It's unclear how the jellyfish use their stinging snot in the wild, but the mucus could be part of a feeding strategy or used in defense against predators. *Cassiopea* jellyfish are unusual in that they rest belly up on the seafloor in tropical waters, letting photosynthetic algae living in the jellyfish tissues produce nutrients that benefit both organisms (*SN: 9/6/14, p. 16*). Upside-down jellyfish in the lab released clouds of mucus when agitated or eating. — *Erin Garcia de Jesus*



Upside-down jellyfish release mucus (the cloudy material in this image) that contains cellular blobs called cassiosomes lined with stinging cells.

FOR DAILY USE

Physicists share the best way to make fried rice

Chefs typically toss fried rice into the air before catching it again in their woks, allowing the food to cook at high temperatures without burning.

Now, physicists have analyzed the repetitive moves made by five Chinese restaurant chefs. By simulating the trajectories of rice tossed from a wok, the researchers hit on some key culinary tips.

Videos show the chefs repeating a set of motions about three times a second: sliding the wok back and forth, while rocking it to and fro using the rim of the stove top as a fulcrum. The rocking and sliding motions shouldn't be totally in sync, otherwise the rice won't mix well and could burn, the researchers report in the Feb. 1 *Journal of the Royal Society Interface*.

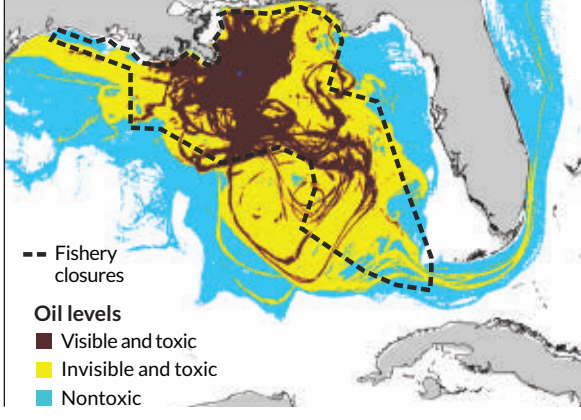
And the wok's movements should repeat rapidly. Moving the wok even faster could launch the rice higher and might allow for cooking at higher temperatures, and perhaps a quicker meal.

But faster shaking may be difficult for chefs to achieve. According to previous studies, chefs at Chinese restaurants can struggle with shoulder pain, and rapidly shaking a wok could be part of the problem. The researchers suggest that a stir-frying robot could be built based on these results, taking the weight off chefs' shoulders. — *Emily Conover*

SCIENCE STATS

Gulf of Mexico oil spill was underestimated

Satellite images overlooked some of the toxic pollution from the Deepwater Horizon oil spill in 2010, an analysis suggests. Those images, taken after nearly 800 million liters of oil poured into the Gulf of Mexico, helped authorities determine which areas to close for fishing. But simulations that factored in ocean currents and oil evaporation suggest those closures (dotted line in the map) covered only about 70 percent of the hazardous area — and missed some spots with oil concentrations high enough to endanger marine life, researchers report February 12 in *Science Advances*. — *Maria Temming*



FROM TOP: ALLEN COLLINS, C. AMES; SERGE BERTASIUS/ISTOCK/GETTY IMAGES PLUS; I. BERENSHTEIN *ET AL*/*SCIENCE ADVANCES* 2020

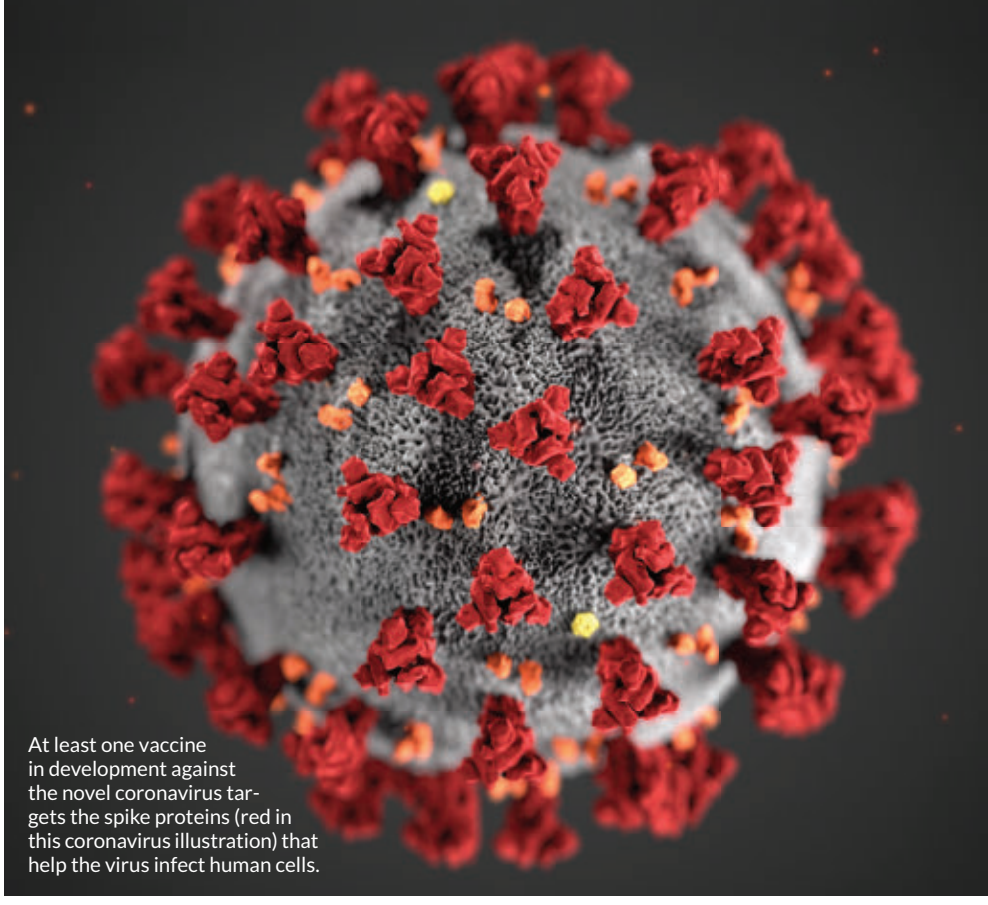
Watch a video of a chef tossing fried rice (with physics) at **bit.ly/SN_friedrice**

BODY & BRAIN

Vaccine scientists target coronavirus

Nontraditional approaches could speed up development

BY TINA HESMAN SAEY



At least one vaccine in development against the novel coronavirus targets the spike proteins (red in this coronavirus illustration) that help the virus infect human cells.

ALISSA ECKERT, MS/CDC

As a mystery illness started spreading in China in late December, researchers at Inovio Pharmaceuticals were keeping an eye on what was happening, even before anyone knew the cause was a coronavirus.

After MERS, caused by a different coronavirus, emerged in 2012, Inovio was one of the first to develop a still-experimental vaccine for the disease. In the new outbreak, as soon as the genetic makeup of the virus, now called SARS-CoV-2, was released, Inovio sprang into action.

"We'd all hoped that there would be enough overlap that our previously developed MERS vaccine would be helpful," says Kate Broderick, Inovio's senior vice president for research and development who is based in San Diego. Like the viruses that cause SARS and MERS, the new virus is a coronavirus that uses RNA as its genetic material.

But in-depth analysis revealed that the two coronaviruses are too different for a vaccine against the virus that causes MERS, or Middle East respiratory syndrome, to take down the new virus. So Inovio set about designing a new vaccine.

That design relies on a relatively new approach to vaccine creation, one that Inovio used to develop the MERS vaccine. Traditional vaccines are made of weakened or killed forms of viruses or parts of viruses, including purified proteins. When injected into a person, the immune system recognizes the virus as an invader and makes antibodies to stave off future invasions. But growing enough debilitated viruses or purifying enough protein to make vaccines for millions of people can take months or years.

Inovio and other companies have developed ways to make vaccines much more quickly. As the number of cases of the novel coronavirus disease, called COVID-19, rises, several groups are racing to develop vaccines that use these nontraditional approaches.

For their new coronavirus vaccine, Inovio scientists convert the virus's RNA into DNA and select pieces of the virus that computer simulations have suggested will prod the immune system into making antibodies. Selected DNA is inserted into bacteria, which produce large quantities of protein snippets for the vaccine. Compared with the two to three years needed to produce a traditional vaccine, Inovio's product took three hours to design and about a month to manufacture, Broderick says.

Inovio started testing in lab animals in early February and hopes to begin safety tests in people by early summer. Even so, the vaccine is still at least a year away from being widely used.

The U.S. National Institute of Allergy and Infectious Diseases is working with the Cambridge, Mass.–based biotech company Moderna to develop a messenger RNA, or mRNA, vaccine that will stimulate the body to make vaccine components. Messenger RNAs are copies of protein-making instructions encoded in the DNA of genes. Cellular machinery reads the instructions to build proteins.

Scientists have selected portions of the new coronavirus that may spark a vigorous immune reaction, says Kizzmekia Corbett, a viral immunologist at the NIAID's Vaccine Research Center in Bethesda, Md. The mRNA vaccine will tell human cells which viral proteins to make. "We're literally giving the cells a genetic code of our vaccine design, delivered as RNA that will tell cells, 'Hey, make this protein,'" Corbett says.

Those proteins will then prod the immune system to make protective antibodies. Since the body does the work, researchers can skip the time-consuming, costly step of manufacturing proteins.

This strategy could be used to design vaccines against other emerging infectious diseases, Corbett says. "What we feel we have developed is a universal strategy, being able to quickly deploy a vaccine if another novel coronavirus should pop up," Corbett says. Other mRNA vaccines against other

diseases are still in the testing phase.

Anthony Fauci, director of NIAID, has said the vaccine could be ready for initial safety testing within months. But the researchers have yet to find a pharmaceutical company that would manufacture the vaccine for the general public, Fauci said February 11 in Washington, D.C., at a discussion of the coronavirus at the Aspen Institute, a nonprofit organization.

Inovio and the NIAID/Moderna partnership have gotten funding from the Oslo-based Coalition for Epidemic Preparedness Innovations. CEPI is also funding development of another novel approach against the new virus. CEPI and scientists at the University of Queensland in Brisbane, Australia, may have found a way to "clamp down" on the virus.

The Queensland group had already been working with CEPI on what are known as molecular clamp vaccines for about a year, says Trent Munro, a biotechnologist involved in the work. A molecular clamp is a protein stitched onto another protein, in this case the coronavirus' spike protein. The spike protein is a bit like a malleable lock pick, changing shape to interact with a protein on the surface of human cells to gain entry. The molecular clamp the team devised prevents the spike protein from shape-shifting, keeping it in a form that triggers antibody production and thus making it a potentially potent vaccine, Munro says.

Mammalian cells make the vaccine, and a special machine determines which cells are churning out clamped protein. With the machine, scientists can "do things that would have taken weeks before in just days," Munro says. Lab testing may start within weeks and safety tests in people may begin in months, but Munro estimates it will be at least a year before the vaccine is ready.

If the outbreak gets bad enough, the U.S. Food and Drug Administration may authorize emergency use of promising vaccines that haven't completed full safety and efficacy testing, Fauci said. But researchers won't know for at least six months whether any of the vaccines in development help against the new coronavirus. ■

GENES & CELLS

Why bat viruses are so dangerous

Ebola and coronaviruses can spread from bats to humans

BY ERIN GARCIA DE JESUS

Viruses from bats are weirdly deadly — at least to humans.

Bats can carry many viruses with the potential to cause serious diseases in people, including coronaviruses. But bats rarely get sick from those viruses. Why these pathogens tend to be so dangerous when they infect other animals has been a mystery.

Previous work suggests that a bat's immune system is especially adapted to tolerate viruses, thanks in part to an ability to limit inflammation. Now a study hints that to counter a bat's defenses, bat viruses have gotten good at spreading rapidly from cell to cell. When they get into animals without a similarly strong immune system, the viruses can cause serious damage, researchers report February 3 in *eLife*.

The study is "an important piece of the puzzle in understanding why viruses [from bats] may be emerging and impacting people and other animals," says Kevin Olival, a disease ecologist at EcoHealth Alliance in New York City who wasn't involved in the research. "There's a lot we can learn from bats about their immune system and take some of that information to think about our own health and developing our own therapeutics," he says.

Scientists have pinpointed bats as potential sources of several outbreaks in humans. Insect-eating bats may have been the source of the 2014–2016 Ebola outbreak in West Africa (*SN: 1/24/15, p. 12*). Egyptian fruit bats harbor Marburg virus, a hemorrhagic virus related to Ebola. Other bats are reservoirs of coronaviruses, possibly including the one that sparked the ongoing outbreak.

Cara Brook, a disease ecologist at the University of California, Berkeley, and colleagues investigated how two bat viruses, Ebola and Marburg, spread upon infecting one of three types of cells in the lab. One cell type, from African green monkeys, lacks an antiviral immune response. The second cell type, from Egyptian fruit bats, sparks an immune response only if infected with a pathogen, and the third cell type, from black fruit bats, is probably in a perpetual state of trying to fight viruses, Brook says.

The team infected the cells with engineered viruses coated with the proteins that either Ebola or Marburg use to infect cells. While the monkey cells were completely destroyed by the viruses, some bat cells survived.

The team re-created the experiment using mathematical simulations to calculate how fast the viruses infected cells and whether antiviral defenses influenced the spread. Viruses replicating under pressure from a bat's immune system have a high rate of cell-to-cell spread within a host, the simulations show. Rapid spread in bat cells helps viruses combat the cells' antiviral properties and quickly mount defenses, the team says. The viruses spread more slowly in the monkey cells, but the cells were swiftly killed.

Pathogens can spread only so fast before they kill their host, Brook says. But if the host has an immune system that can defend against rapidly spreading viruses, a virus might evolve to infect cells even faster than it would in a different environment. If a quick-spreading virus from bats were to infect another species that lacked batlike defenses, "it would probably cause extreme virulence," Brook says.

There are more than 1,400 bat species in the world, Olival says, and the current study focused on only two. "It's important to remember that all other bat species might have totally different responses as well," he says.

Olival is also curious how the findings might apply to other animals that carry deadly viruses, such as rodents. "Bats are not the only mammal that are reservoirs for human zoonotic viruses," he says. "The question is not only how do bats cope with viruses, but how do other mammal species that are reservoirs cope with the viruses they carry?" ■

LIFE & EVOLUTION

Beaked whales get in sync to stay safe

Peculiar diving behavior is a way to hide from predators

BY JONATHAN LAMBERT

Beaked whales have evolved a sneaky trick for evading detection by a foe.

An unusual, highly synchronized style of diving, which researchers describe February 6 in *Scientific Reports*, helps the whales slip past killer whales when surfacing to breathe. Predation from killer whales has shaped that behavior, the scientists say, and it might explain why naval sonar exercises, which can sound like predators to beaked whales, cause mass beaching events (*SN: 4/23/11, p. 16*).

Sperm and pilot whales have the size or muscle to flee or defend against killer whales. Smaller prey, like dolphins, find safety by swimming in large pods. Certain toothed whales even communicate in frequencies killer whales can't hear.

A Cuvier's beaked whale surfaces off the coast of Spain's Canary Islands.

But elephant-sized beaked whales, named for their pointy snouts, have none of these advantages. These extreme divers swim in small groups, can't outswim killer whales and rely on audible clicks to echolocate food in the deep. Killer whales (*Orcinus orca*) should be able to hear beaked whales hunting below and easily pick them off as they ascend.

Previous research has hinted that when beaked whales return from the deep sea, they often don't come straight up for air like other whales. Instead, they ascend at a gradual angle, surfacing far from where they dove. "It's highly unusual for whales to do this," says marine biologist Natacha Aguilar de Soto of the University of La Laguna in the Canary Islands, Spain.

She and colleagues suction-cupped sensors onto 14 Blainville's beaked whales (*Mesoplodon densirostris*) and 12 Cuvier's beaked whales (*Ziphius cavirostris*) off Spain, Portugal and Italy to better understand this diving behavior. The sensors tracked depth, orientation and sound. Instead of diving for food whenever an individual got hungry, tagged whales in the same group dove together 99 percent of the time.

On their way down, the whales remained totally silent. But once they reached about 450 meters deep, they split up, loudly chirping to echolocate prey hundreds of meters from other group members.

Killer whales cannot hunt mammals this deep. But, Aguilar de Soto says, the predators can eavesdrop on beaked whales while they hunt and could hover above, waiting for them to ascend.

When the beaked whales finished foraging, they regrouped and began a silent, meandering ascent to the surface,

ATOM & COSMOS

Physicists force muons to chill out

Feat is a step toward higher-energy particle smashups

BY EMILY CONOVER

From electrons to protons to atomic nuclei, physicists love smashing tiny stuff together. And soon, they may have an even better way to get their kicks.

A new experiment raises prospects for building a particle accelerator that collides particles called muons, which could lead to smashups of higher energies than any engineered before. Scientists with the Muon Ionization Cooling Experiment have cooled a beam of muons, a necessary part of preparing the particles for use in a collider, the team reports in the Feb. 6 *Nature*.

To study matter at its most fundamental level, physicists smash particles together at high energies and filter through the wreckage. The strategy has revealed previously unknown particles, such as the Higgs boson (*SN: 7/28/12, p. 5*), discovered at the Large Hadron Collider at CERN, near Geneva, in 2012.

That 27-kilometer collider is the biggest machine ever built. To keep searching for new particles, scientists must go to higher energies. The higher a collision's energy, the heavier the particles scientists might be able to find. Getting to higher energies requires a more powerful accelerator. So scientists are planning bigger, badder — and pricier — versions of current colliders (*SN: 2/16/19, p. 14*).

But colliders that bang protons together, such as the LHC, have a major drawback: Protons are made up of smaller particles called quarks, each of which carries only a fraction of the proton's energy. So each particle crash has less oomph. Collisions of fundamental particles like muons, which aren't made of smaller particles, don't have that problem.

Some colliders skirt the proton problem by smashing electrons and their antimatter opposites, positrons. Those machines also have a drawback: Electrons and positrons lose energy circling around an accelerator ring by spewing X-rays. Those rays are less important for heavier particles like muons, which are about 200 times as massive as electrons, allowing muons to reach higher energies.

But colliding muons is no simple feat. To create muons, scientists slam a beam of protons into a target, creating other particles that decay and produce muons. Those muons emerge with a variety of different energies and directions. To use the particles in a collider, they must be cooled, or shepherded into an orderly formation, just as cooling a gas reduces the haphazard motion of its atoms.

N. AGUILAR/UNIV. OF LA LAGUNA

traveling an average of a kilometer from where they dove.

"That's the trick to give the skip to killer whales," Aguilar de Soto says.

The researchers estimate that a killer whale can visually explore only 1.2 percent of the potential surfacing area of the beaked whales. Beaked whales' diving behavior allows groups, which often include young whales, to stay together while also evading detection.

"This study is a great achievement; it's really hard to get good data on these whales," says Nicola Quick, a behavioral ecologist at Duke University. The work supports the idea that predation has shaped this unusual diving behavior, although the gradual ascent also could be important for avoiding decompression sickness, she says.

Aguilar de Soto says the study helps to explain why beaked whales react so strongly to sonar. Having evolved in a "soundscape of fear," she says, the whales may be hypersensitive to the sounds of predators. Sonar might hijack this response and drive disoriented, scared whales to swim until they're beached. ■

Without this cooling, muons won't collide when two particle beams are crossed. "The beam is too diffuse, and the muons just miss each other," says physicist Chris Rogers of Rutherford Appleton Laboratory in Didcot, England.

To achieve cooling, Rogers and colleagues pass muons through materials, causing the muons to knock electrons off of atoms in the material. That saps some of the muons' momentum in all directions. The next step will be to accelerate the muons all in the same direction using electromagnetic fields. Repeating this process multiple times will produce a suitably dense, orderly beam.

The method "can drastically change the way we build big accelerators," says accelerator physicist Vladimir Shiltsev of Fermilab in Batavia, Ill., who was not part of the work. "What we are talking about right now is the dawn of a new possible era in particle physics and definitely in accelerator beam physics." ■

LIFE & EVOLUTION

Frog-killing fungus harmed snakes too

Outbreak in Panama probably wiped out food supplies

BY JONATHAN LAMBERT

Karen Lips knew a wave of frog death was coming.

A frog-killing chytrid fungus called *Batrachochytrium dendrobatidis* had begun ravaging amphibian populations in Costa Rica in the early 1990s and, by all indications, would eventually reach Panama. So in 1997, Lips, a herpetologist now at the University of Maryland in College Park, and colleagues scrambled to take stock of the biodiversity at Panama's El Copé tropical forest field site before the wave hit.

The fungus arrived at El Copé in 2004, eliminating more than 75 percent of the amphibian population there. Lips and colleagues' foresight allowed them to assess the chytrid's impact on another part of that ecosystem — snakes.

Both snake diversity and average body size dipped after the chytrid wiped out the frogs, a major food source for snakes, the team reports in the Feb. 14 *Science*.

"When there's a collapse [like that in frogs after the chytrid], the focus is usually on the group that collapsed," says Kelly Zamudio, an evolutionary biologist at Cornell University who wasn't involved in the research. But the new study makes key strides toward documenting the effects of a collapse on other parts of an ecosystem. "It's an intuitive idea," she says, but one that has been difficult to demonstrate because biologists need good before-and-after data.

Lips' team looked for amphibians and reptiles along 200- to 400-meter paths at El Copé each year from 1997 to 2012. The team caught whatever it could, noting the species and measuring body size.

The number of observed snake species declined after the chytrid's arrival, from 30 to 21. But since encounter rates are low for many of these snakes — a dozen of the 36 species ever observed at the site were seen only once in 13 years — simple statistics can't tell the full story.

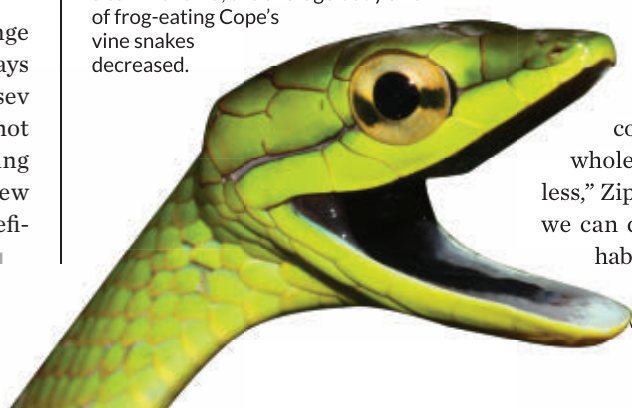
So Elise Zipkin, a quantitative ecologist at Michigan State University in Lansing, devised a different strategy. She and colleagues used the observational data to run statistical simulations estimating the probability that both observed and unobserved snake species were present in a particular path before and after the chytrid. "We can say with 85 percent probability that there are fewer species present after," she says.

Average body size also went down, perhaps due to lack of food, for four of the six species seen often enough to measure.

A handful of snake species benefited from the frog disappearance. Four became more common, perhaps because they have more varied diets. The eyelash viper (*Bothriechis schlegelii*), the biggest winner, dines on birds, bats and rodents in addition to frogs.

"Overall, chytrid has probably left things worse off for snakes," Zipkin says. Rare species have disappeared, leaving a smaller, more homogenous community behind. Similar patterns may be occurring elsewhere in ecosystems affected by other threats, she says. "The biodiversity crisis is probably worse than we're even able to estimate."

But just as the collapse of one group can send shock waves throughout an ecosystem, lifting the health of a species or community could also benefit the whole. "I really don't think it's hopeless," Zipkin says. "There's still so much we can do, like preserving remaining habitats, to preserve biodiversity." ■



After a fungus ravaged amphibians at a field site in Panama, the average body size of frog-eating Cope's vine snakes decreased.

KEVIN ENGE

MATH & TECHNOLOGY

AI bests humans in crime predictions

New study is more realistic but doesn't account for biases

BY MARIA TEMMING

Computer algorithms can outperform people at predicting which criminals will get arrested again, a new study finds.

Risk-assessment algorithms often help judges and parole boards decide who stays behind bars. But these systems have come under fire for showing racial biases. And a 2018 study found that humans predicted repeat offenses about as well as a commonly used tool called COMPAS.

The new study confirms that humans predict repeat offenders about as well as algorithms when given immediate feedback on the accuracy of their predictions and when shown limited information about each criminal. But people are worse than computers when not given feedback or shown more detailed criminal profiles.

Judges and parole boards don't get instant feedback, and they usually have a lot of information. So the study's findings suggest that, under realistic conditions, algorithms outmatch people at forecasting recidivism, researchers report February 14 in *Science Advances*.

Sharad Goel, a computational social scientist at Stanford University, and colleagues first re-created the 2018 study. Online volunteers read short descriptions of 50 criminals — including details like sex, age and number of past arrests — and guessed whether each person was likely to be arrested for another crime within two years. After each round, volunteers were told whether they guessed correctly. People rivaled COMPAS' performance: accurate about 65 percent of the time. Even without feedback, people achieved 62 percent accuracy.

But in a slightly different version of the experiment, COMPAS had an edge over people who did not receive feedback. Participants had to predict which of 50 criminals would be arrested for violent crimes, rather than just any crime.

With feedback, humans performed the task with 83 percent accuracy — close to COMPAS' 89 percent. Without feedback, human accuracy fell to about 60 percent. People tended to overestimate the risk of criminals committing violent crimes. The study didn't investigate whether racial or economic biases contributed to the trend.

In a third variation of the experiment that involved reviewing more detailed criminal profiles, software called LSI-R — which could consider 10 more risk factors than COMPAS, including substance abuse, level of education and employment status — outperformed people. Criminals with the highest risk of getting arrested and reincarcerated again, as ranked by people, included 58 percent of actual repeat offenders; LSI-R's list had about 74 percent of actual reoffenders.

Computer scientist Hany Farid of the University of California, Berkeley, who worked on the 2018 study, says that just because algorithms outmatch untrained volunteers doesn't mean they should be trusted. Since neither humans nor algorithms showed great accuracy at predicting whether someone will commit a crime two years down the line, Farid questions whether those forecasts should be used. Perhaps other questions, like how likely someone is to get a job or jump bail, should factor more heavily into criminal justice decisions, he says. ■

MATH & TECHNOLOGY

Robots inch closer to 'feeling' pain

Touch sensor tells robotic child when to mimic emotion

BY LAURA SANDERS

SEATTLE — A robot with a sense of touch may one day "feel" pain. Touchy-feely robots are still far off, but advances in robotic touch-sensing bring that possibility closer to reality.

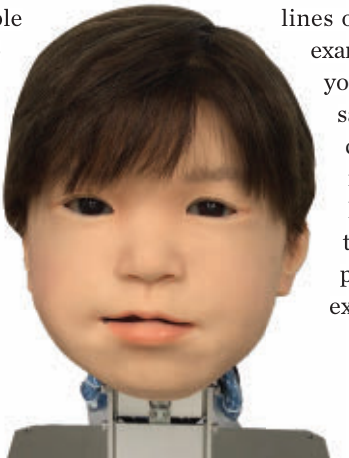
Sensors embedded in soft, artificial skin that can detect both a gentle touch and a "painful" thump were hooked up to a robot that can then signal emotions, engineer Minoru Asada reported at the American Association for the Advancement of Science's annual meeting on February 15. This artificial "pain nervous system," as Asada calls it, may be a small building block for a machine that could experience pain, in a robotic sort of way.

Asada, of Osaka University in Japan, and his colleagues designed touch sensors that reliably pick up a range of touches. In a robot system named Affetto, which looks like a child's head, these touch and pain signals can be converted to facial expressions.

Such a system, Asada says, might lead to robots that can recognize the pain of others, a valuable skill for robots designed to care for the elderly, for instance.

But there is an important distinction between a robot that responds in a predictable way to a painful thump and a robot that's capable of approximating an internal feeling, says neuroscientist Antonio Damasio of the University of Southern California in Los Angeles. He and a colleague argued in 2019 that something resembling a sense of feeling might arise if robots were programmed to experience something akin to a mental state such as pain.

A robot with tactile sensors that can detect touch and pain is "along the lines of having a robot, for example, that smiles when you talk to it," Damasio says. "It's a device for communication of the machine to a human." But that's different than a robot that computes a sort of internal experience, he says. ■



Touch sensors help Affetto, a robot built to resemble a child, detect a signal that would cause pain to a human.

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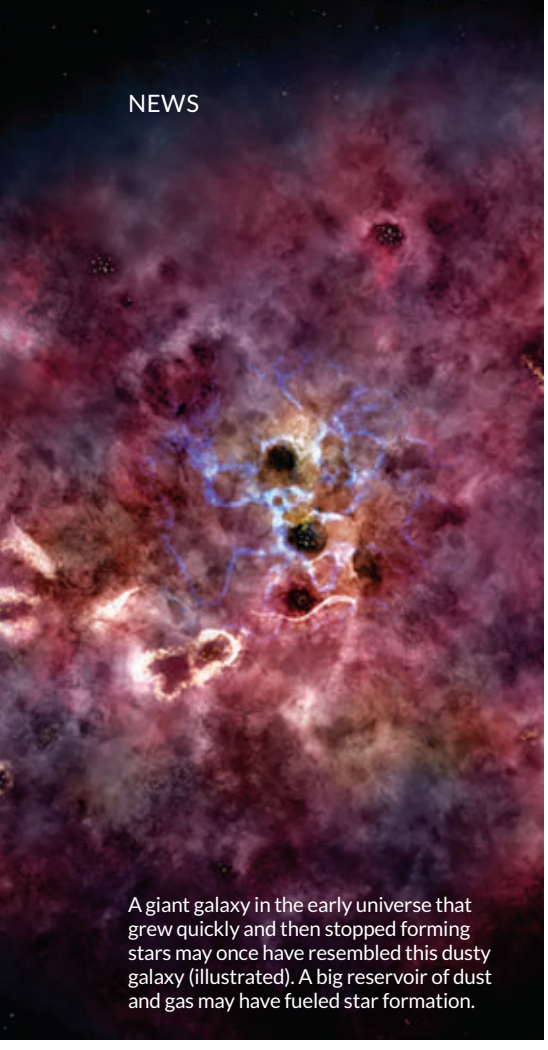

A giant galaxy in the early universe that grew quickly and then stopped forming stars may once have resembled this dusty galaxy (illustrated). A big reservoir of dust and gas may have fueled star formation.

ATOM & COSMOS

What tamed a galactic monster?

A prolific early galaxy suddenly stopped churning out stars

BY CHRISTOPHER CROCKETT

Even galaxies burn out if they work too hard. A galactic monster in the early universe quit forming stars after ferociously churning them out for hundreds of millions of years, researchers report. Why the galaxy slacked off is unclear, but the answer might teach astronomers a thing or two about how the earliest galaxies grew and evolved into the stellar metropolises that surround us today.

The galaxy's light took nearly 12 billion years to reach Earth. So astronomers see the galaxy, called XMM-2599, as it was just 1.8 billion years after the Big Bang. By that time, the galaxy had bulked up to a mass of about 300 billion suns, observations show, making it three times as massive as similar galaxies from that epoch.

The galaxy appears to have gotten so hefty by cranking out stars at a rate of over 1,000 solar masses per year for several hundred million years. But then, the star-making suddenly stopped, Benjamin Forrest of the University of California, Riverside and colleagues report in the Feb. 10 *Astrophysical Journal Letters*. By comparison, the Milky Way produces just a few stars per year.

"This paper is telling us that star formation can be very, very efficient in the early universe and equally efficiently be quenched," says Mauro Giavalisco, an astronomer at the University of Massachusetts Amherst who was not involved with this study.

Galaxies make stars as long as they have a supply of cold gas; the Milky Way has been at it for nearly the entire 13.8-billion-year history of the universe. The only ways to shut down star formation are to prevent cold gas from raining down on the galaxy or to physically remove the gas, Giavalisco says. "Theory doesn't quite fully explain how to stop so quickly and efficiently star formation in a galaxy which, only a little bit earlier, was forming stars with prodigious efficiency."

HUMANS & SOCIETY

West Africans carry 'ghost' genes

An ancient, unknown population's DNA lives on in some people

BY BRUCE BOWER

An ancient, humanlike population still undiscovered in fossils left a genetic legacy in present-day West Africans.

This extinct relative of *Homo sapiens* passed genes to African ancestors of modern Yoruba and Mende people starting around 124,000 years ago or later, report UCLA geneticists Arun Durvasula and Sriram Sankararaman. Surviving DNA of that ancient hominid is different enough from that of Neandertals and Denisovans to suggest an entirely different hominid was the source.

Yoruba and Mende groups' genomes contain 2 to 19 percent of genetic material from this "ghost population," the team reports February 12 in *Science Advances*. Some DNA passed down from the ghost population influences survival-enhancing functions, including tumor suppression and hormone regulation.

DNA samples from Han Chinese in Beijing and from Utah residents with European ancestry also show signs of ancestry from the mysterious population, the team found. But DNA from those two groups was not studied as closely as that from the Yoruba and Mende people.

The report adds to recent evidence that interbreeding of ancient people with various *Homo* species played a bigger role in the evolution of modern Africans than has generally been assumed. For instance, after leaving Africa about 60,000 to 80,000 years ago, *H. sapiens* groups interbred with European Neandertals before taking Neandertal DNA back to Africa starting about 20,000 years ago, another team has concluded (*SN: 2/29/20, p. 6*). Those researchers found that Neandertal DNA accounts for, on average, about 0.5 percent of individual Africans' genomes, far more than in earlier studies. Most people outside Africa carry about three times as much Neandertal DNA as Africans do.

Ghost hominid DNA and Neandertal DNA appear to have made separate inroads among humans in Africa at about the same time, says geneticist Iain Mathieson of the University of Pennsylvania Perelman School of Medicine.

Ancient humans trekking back to Africa already might have mated with members of the ghost population, but "it is more likely that interbreeding happened in Africa," Sankararaman says. That possibility is supported by the fact that several Late Stone Age African *H. sapiens* fossils — some dating to as late

NRAO/AUI AND NSF, B. SAXTON

Other prolific star-forming galaxies existed in the early universe, including a few that also had retired. But none is known to be as massive as XMM-2599, Forrest says.

A supermassive black hole in the galaxy's center may be to blame. Such a black hole likely would have attracted a superheated whirlpool of cosmic detritus, which blazed with light that energized gas around the galaxy, preventing it from coalescing into clumps needed to birth stars. Alternatively, the stars may have brought their own undoing. Lots of star formation leads to lots of supernovas, Giavalisco says, which could have ejected gas on a galactic scale.

By looking for similarly quiet monsters, researchers could "confirm whether this thing is just a one-off, weird galaxy ... or if it's part of a larger population," Forrest says. As for what becomes of such a galaxy, that's hard to say. But Forrest and Giavalisco speculate that, over time, its gravity may attract other galaxies, possibly making XMM-2599 and its ilk the seeds around which galactic clusters grow. ■

as about 16,000 years ago — display traits like those of much older *Homo* species, including Neandertals, he says.

Precisely how these genetic exchanges played out is hard to know because researchers lack fossils from the ghost population from which to extract DNA, says geneticist Pontus Skoglund of the Francis Crick Institute in London.

Durvasula and Sankararaman compared genomes of 405 West Africans, more than half either Yoruba or Mende, with ancient DNA from a roughly 44,000-year-old Neandertal fossil from Europe and a 51,000-year-old Denisovan fossil from Siberia. Patterns of single DNA unit changes, called SNPs, enabled the team to identify areas across Yoruba and Mende genomes that were inherited from a line of hominids other than Neandertals and Denisovans. That ghost population diverged from direct ancestors of Yoruba and Mende over 1 million years ago, the scientists estimate. ■

EARTH & ENVIRONMENT

Noise pollution disturbs arctic cod

Increased shipping traffic may disrupt the fish's foraging

BY GLORIA DICKIE

Noise of ships is causing arctic cod to sacrifice feeding to flee the area until the vessels move away, researchers report.

The finding is cause for concern as climate change increases sea ice melt in the Arctic, drawing more ships to the region, researchers say in the study, which will appear in the April *Ecological Applications*.

"The results were staggering," says Aaron Fisk, a biologist at the University of Windsor in Canada. Fish use sound for foraging, avoiding predators, navigating and communicating. Noise pollution could threaten those behaviors, he says.

Fisk and colleagues recorded ship locations in August and September 2012 while acoustic tags tracked 77 cod in northern Canada's Resolute Bay. The team compared the fish data with footage of the ships to determine whether the fish were moving in response to the vessels.

When no ships were present, the cod stayed in one area of a 30-meter-deep depression in the bay. But when a ship passed — creating sounds as loud as 147 decibels, similar to the noise from a motorcycle engine, and much more than the bay's ambient noise level of 74 decibels — the fish stopped feeding and fled. They swam up to 350 meters away for up to 30 minutes. That means the fish were spending more energy swimming and less time gaining calories, Fisk says.

Because most shipping occurs in summer, the crucial open-water feeding period for marine species, acoustic disturbances could impact the food web. Schools of arctic cod (*Boreogadus saida*) appear almost like "big oil slicks," moving in patterns that predators may have come to rely on, Fisk says. "It's likely marine mammals are keyed into those times. If shipping activity disrupts the schools, that will cascade down to seals, whales, polar bears and the Inuit who use those mammals as a food source."

Traffic is expected to grow as dwindling sea ice opens a direct route between North America and Asia through the Northwest Passage. Already, the number of ships has gone from about four per year in the 1980s to 27 in 2019.

The cod also face other threats, such as the loss of sea ice that protects eggs from damage by waves and currents. Warming seawater also prevents the cod from foraging in surface waters when it's really warm in summer, says Helen Drost, a zoologist at the University of British Columbia in Vancouver.

"Add noise to that, and you've got one more thing" stressing the fish, she says. "It's significant if [cod] are being frightened by ships into areas that aren't their optimum habitat, or away from their prey, because they already have such a short season to fatten up."

More work is needed to understand the impact of noise, but "these kinds of studies that assess the movements of animals are more important than ever," Fisk says. "We don't have a good handle on what's going on in the Arctic." ■

Arctic cod flee the noise of passing ships. As shipping in the Arctic increases, the fish might struggle to accrue calories.

EARTH & ENVIRONMENT

Methane emitter is underestimated

Fossil fuels may be a bigger source of the gas than thought

Oil and natural gas facilities burn off some methane with flaring, but the gas also escapes to the atmosphere via leaky pipes and venting.

BY CAROLYN GRAMLING

The fossil fuel industry releases much more of the potent greenhouse gas methane than previously thought — possibly 25 to 40 percent more, new research suggests. The finding could help scientists and policy makers target how and where to reduce these emissions, researchers report in the Feb. 20 *Nature*.

The amount of methane released from geologic (rather than biological) sources is 172 trillion to 195 trillion grams, or teragrams, per year. Geologic methane sources include the oil and gas industry as well as natural sources such as mud volcanoes and offshore gas seeps. Previous estimates indicated that the natural portion of geologic emissions is 40 to 60 teragrams of methane each year, with the remainder from fossil fuels.

But new analyses of more than two centuries of methane preserved in ice cores suggest that natural sources — both in the past and in modern times — send far less methane into the atmosphere than once thought. That means that modern human activities are responsible for nearly all of the current geologic emissions of methane, atmospheric chemist Benjamin Hmiel of the University of Rochester in New York and colleagues conclude.

Methane has about 80 times the atmosphere-warming potential of carbon dioxide, but only on short timescales. Methane lingers in the atmosphere for only 10 to 20 years, while CO_2 can linger for hundreds of years. "So the changes we make to our [methane] emissions are going to impact the atmosphere much more quickly," Hmiel says.

Coal mining, natural gas and other fossil fuel sources pushed atmospheric methane levels upward through the 20th century. Emissions tapered off in the first few years of the 21st century. But beginning in 2007, methane levels began to increase again and are now increasing at rates not seen since the 1980s.

What's causing the post-2007 buildup isn't clear. Previous work suggests that much of it is biological: amped-up microbial activity in wetlands — possibly linked to changes in rainfall — and more cow burps. Geologic sources like leaky pipelines also contribute. And less atmospheric methane may be getting broken down (*SN: 5/13/17, p. 14*).

If methane emissions continue rising, meeting the greenhouse gas reduction goals of the Paris Agreement will be difficult, says Euan Nisbet, a geochemist at Royal Holloway, University of London, who was not involved in the study. So identifying the portion of the methane bump linked to the oil and gas industry offers chances for targeted reductions.

To calculate today's methane emissions from all geologic sources, scientists need to establish a baseline for preindustrial emissions from natural sources like seeps and mud volcanoes. In the new study, the team turned to methane preserved in ice cores from Greenland dating from about 1750 to 2013.

The team first had to distinguish methane produced from geologic versus biological sources in the ice core record. Biological sources produce methane with relatively high levels of radioactive carbon-14; methane from geologic sources tends to be very old, so the carbon-14 has long since decayed away.

Before the Industrial Revolution, the team discovered, methane emissions from geologic sources were about 1.6 teragrams per year on average — and no more than 5.4 teragrams per year at their highest. That's an order of magnitude smaller than previous estimates.

Subtracting that amount from total methane emissions today, the team calculates that nearly all of the 195 teragrams of geologic methane measured today is from human actions.

"Paradoxically, that's actually a hopeful finding," Nisbet says. Stopping gas leaks and reducing coal mine emissions are relatively easy ways of cutting greenhouse gas emissions, he says. So reducing methane emissions offers "an even bigger opportunity" for reducing greenhouse gases overall.

But such ice core–based work is not yet proven to be the most accurate technique to estimate natural geologic emissions, says Stefan Schwietzke, an environmental scientist with the Environmental Defense Fund who is based in Berlin. The ice core information is useful because it gives an immediate global snapshot of methane emissions, but "it has the challenge of interpretation and a lot of very complex analysis," Schwietzke says.

Direct measurements of methane emitted from different seeps or over mud volcanoes suggest much larger natural emissions, he adds. The problem with this method, however, is that it's difficult to scale up from local measurements to a global number. "To really understand the magnitudes, these two methods need to be reconciled," Schwietzke says.

He and other researchers have proposed using remote sensing to reconcile the two techniques. Airborne measurements can give a bigger-picture estimate, while also identifying local hot spots. Scientists have used airborne remote sensing to identify sources such as leaking pipelines and landfills (*SN: 12/7/19, p. 6*). Similar projects are tracking emission hot spots in the Arctic.

Still, Schwietzke says, this debate over the methane-detection technique doesn't change the fact that human-caused emissions, including fossil fuels, are responsible for the dramatic rise of atmospheric methane over the last century. "It is very large. And reducing those emissions will reduce warming." ■

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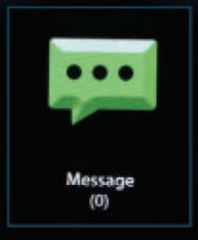

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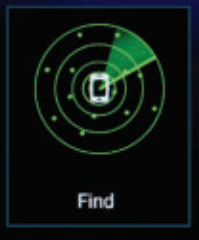

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THE RACE BOX

How we ask the census question matters

By Sujata Gupta

Wendy Roth has been arguing for years that the U.S. Census Bureau should ask about race in a different way. The race box that people check for themselves on the census doesn't always match the box someone else might have checked for them. And that, Roth says, is a problem.

Roth, a sociologist at the University of Pennsylvania, began researching that mismatch in racial identification in the early 2000s. She recruited 60 New Yorkers who had been born in Puerto Rico or the Dominican Republic, showed them the census race question and asked them how they would answer. The responses surprised her.

Consider the case of Salvador, a kitchen worker in the Bronx. "Many Americans observing him would consider him to be black," Roth wrote in December 2010 in *Social Science Quarterly*. But Salvador told Roth that he checks "white."

While attitudes in the mainland United States have been shaped by the long legacy of the "one-drop rule," in which a single drop of "black blood" conferred "blackness," Puerto Ricans believe the opposite — that even dark-skinned people can't be black if they have "white blood." Puerto Ricans use terms like *mulatto* or *trigueño* to describe those falling somewhere between white and black. But when presented with race checkboxes that offer no intermediate options, Salvador simply goes by what he knows.

People from the Dominican Republic, who have long viewed themselves as "whiter" than their Haitian neighbors, likewise avoided checking "black." Roth found that Dominicans selected "white" or "some other race" and then wrote in descriptors, such as Latino or Hispanic.

"There are a lot of other people who don't understand how to complete the U.S. census ...

DELPHINE LEE

because it doesn't match their way of understanding race," Roth says. "Sometimes they will identify in ways that are the complete opposite of what the U.S. census is trying to capture."

The census race question is trying to capture the changing demographic composition of the country from the federal and state levels down to neighborhood blocks. The stated aim — at least for the last half century — is to help policy makers and demographers assess whether members of different racial groups have equal access to housing, education, employment and other services, as mandated by law.

Population counts from the census, which has run every 10 years since 1790 (see Page 22), are used to determine a state's electoral vote count and how many seats a state receives in the House of Representatives. Those data also serve as the denominator for different demographics by age, sex and race. Data gathered by other government agencies provide the numerator, such as the number of children by race in schools or the racial makeup of the prison population, says Katherine Wallman, former chief statistician of the Office of Management and Budget. The OMB makes sure every federal government agency uses the same racial and ethnic categories in data collection.

Imagine, for instance, that the National Center for Education Statistics identifies a high school as having a student body that is 90 percent black and 10 percent white. But the census data show that the school serves a region that is 50 percent black and 50 percent white. That suggests the school is more racially segregated than the surrounding region. Accurately capturing that sort of discrimination in schools requires reliable race data, both for the numerator and the denominator.

The census, though, operates under the premise that people will identify themselves in the same way as those in their society see them. For instance, a person like Salvador will check "black." When a person's view of their own race aligns with that of the broader society, the race data can point to areas of inequality and potential discrimination.

But people who don't identify with the census race boxes may check a box that doesn't reflect how society sees them. Or they may skip the question or fail to return the form, resulting in undercounts, and the race data stop working as intended.

"Discrimination is more about how you're seen by others than how you see yourself," Roth says.

That capture problem is expected to crop up again with the 2020 census. For the race question, a representative from every household, answering online for the first time, will see options within five racial categories: White; Black or African-American; American Indian or Alaska Native; Asian; and Native Hawaiian or other Pacific Islander. The OMB established those categories in 1997. Federal agencies are allowed to ask for more detail within those categories. That's why Asians answering the census can select from Chinese, Filipino, Asian Indian, Vietnamese, Korean, Japanese and other Asian. Native Hawaiians and other Pacific Islanders can choose Native Hawaiian, Samoan, Chamorro or other Pacific Islander. Respondents can also check "some other race" or multiple race boxes.

"Discrimination is more about how you're seen by others than how you see yourself."

WENDY ROTH

Missing from that list are two groups that had hoped to find their own race checkbox in the 2020 census: Hispanics and people from the Middle East and North Africa. As in past censuses, members of both groups will mostly select "white" or "some other race," which can make it harder to locate where there may be a need for local bilingual services in schools or during elections, for example.

Plus, there's a new wrinkle brought on by the growing popularity of genetic ancestry tests: Roth's recent work shows that white people have been checking nonwhite boxes on the census as an expression of their newfound genetic history. "They are searching for an identity that is more specific, more interesting than being just white," Roth says.

That murkiness in the race data has prompted Roth and other sociologists to call for more nuanced race questions. There are ways, the researchers say, to get at both how respondents view themselves — which can help build a group's social and political power — and how they are viewed by society, a clearer metric for measuring discrimination against people like Salvador.

"I would love it if [the Census Bureau] actually measured the thing that they were trying to measure," Roth says.

Equity meets frugality

Up until relatively recently, the race question's raison d'être was not to undo racial segregation but to justify practices that separated racial groups, such as the South's Jim Crow laws. But starting about 50 years ago, following the civil rights movement, the purpose of the race question was flipped on its head.

How the U.S. census has framed race over time

1790: The first U.S. census counts free whites, slaves and other free persons, adding up to 3.93 million.

1820: A new category, "free blacks," is added, indicating that the free black population was growing and had different rights than whites.

1850: This census includes the terms "mulatto" and "mulatto slaves" to describe people who were black and another race.

1870: "Chinese" race is added to the national census form. It takes 6,500 marshals and assistants to count the U.S. population, which by this time is nearing 40 million people.

1880: The enumerators hired to carry out the census are instructed to pay careful attention to each respondent's "color."

1890: American Indians living on reservations are counted. "Japanese" is added, and blacks are divided into "black," "mulatto," "quadroon" and "octoroon."

1800

1900

1860: "Indian" appears on the census for the first time, but only for counting American Indians who had assimilated into white communities.

An enumerator, seated, collects census data from four people from the Winnebago Tribe in Wisconsin circa 1911.

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The civil rights movement led to the gradual dismantling of laws and practices that blocked minorities from certain schools, jobs or neighborhoods and led to the passage of new laws, such as the Civil Rights Act of 1964, the Voting Rights Act of 1965 and the Fair Housing Act of 1968, in an attempt to provide equal opportunity for all.

Meanwhile, up through the 1950 census, specially trained enumerators who visited people's homes filled out the form for each family, including the section on race. Asking directly about race was considered rude, says sociologist Carolyn Liebler of the University of Minnesota in Minneapolis. So enumerators eyeballed the person at the door and made a decision.

Assuming that most people they came across were black or white, enumerators seldom reported American Indian as a race, and they often didn't consider that other family members may be of a different race. In the 1950 census, for instance, enumerators were instructed to "assume that the race of related persons living in the household is the same as the race of your respondent, unless you learn otherwise."

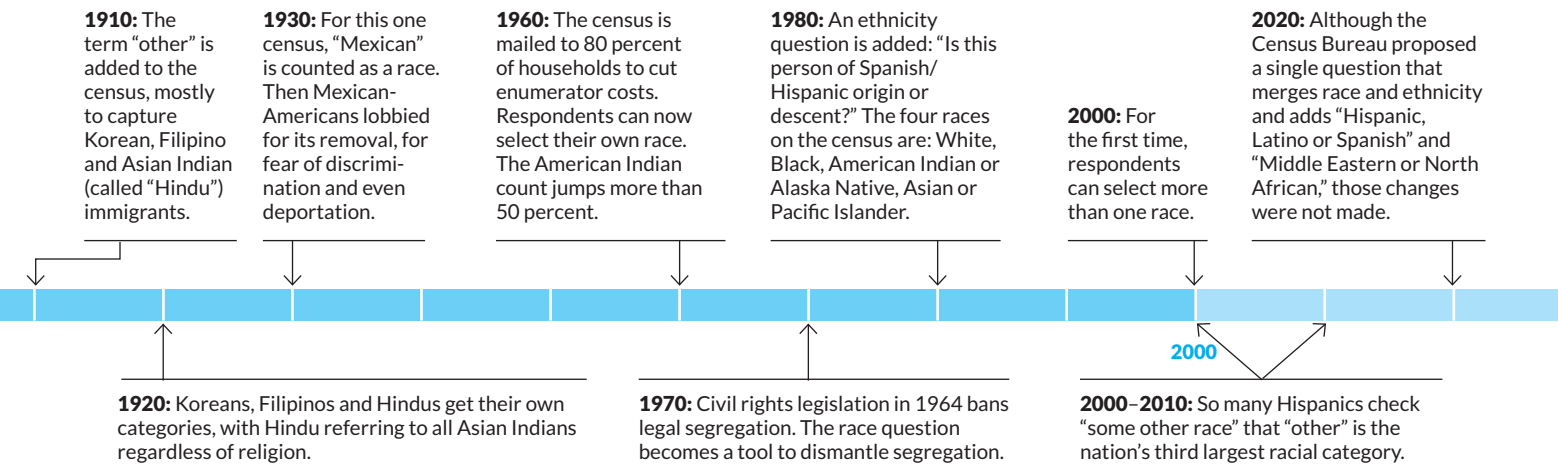
Starting in 1960, though, officials made a money-saving decision with far-reaching consequences: They started cutting back on enumerators. By the 1980 census, almost all households received the census in the mail, and enumerators visited only those households that failed to respond to the questionnaire in a timely manner. Crucially, for the last half century, the vast majority of respondents have been identifying their own race.

So just as the Census Bureau started relying on the race question to quantify discrimination, the agency switched away from using nonfamily members to check the race box. Those seemingly unrelated changes converged to obscure the new-and-improved purpose of the race question.

Most people answering the census don't see the race question as a way for federal agencies to track discrimination, they assume the question is asking them to express their racial identity, says sociologist Ann Morning of New York University who served from 2013 to 2019 on the National Advisory Committee on Racial, Ethnic and Other Populations, a group appointed by the director of the Census Bureau.

Where's my box?

The enumerators who checked boxes for other people had little reason to take offense at the available race categories. But when respondents started filling out the census themselves, the absence of an appropriate checkbox felt like an affront. Consider individuals from Middle Eastern or North African, called MENA, countries, such as Algeria, Egypt, Iran and Lebanon. The OMB defines



such individuals as white. But since the 1980s, people who trace their roots to those countries have been calling for a separate MENA checkbox.

"We believe the MENA classification should be its own separate classification divorced from the white classification," says Khaled Beydoun, a law professor and author at the University of Arkansas in Fayetteville.

With the government doling out more than $880 billion in 2016 alone toward census-guided federal programs, a separate designation would enable policy makers to funnel some of that money to MENA communities seeking the American dream. While such dollars are rarely allocated solely on race, except in the case of American Indians, many federal granting agencies will put applications aimed at minority and underserved racial and ethnic populations at the top of the pile, says Andrew Reamer, an economic and statistical policy expert at George Washington University in Washington, D.C. When groups like MENA are folded into the white category, their applications stay buried.

While some worry that checking "MENA" instead of "white" could lead to increased government surveillance of MENA communities, Beydoun and others say the opposite. A separate MENA checkbox would signify that the United States acknowledges such groups outside the lens of counterterrorism and surveillance, Beydoun says. "For the community, it would be symbolic."

Hispanic case study

Hispanics also don't have a race checkbox, but the Census Bureau has been counting that population since 1980. That's when every household in the United States began answering an ethnicity question alongside the race question: It asks if the person is of Hispanic, Latino or Spanish origin.

That data revealed that 14.6 million Hispanics were living in this country in 1980 — accounting for 6.4 percent of the U.S. population. By the last census in 2010, that number had risen to 50.5 million, or 16 percent of the population. As Hispanics' numbers and visibility increased — in large part thanks to their census designation — bilingual Spanish-English schools became more popular, television programs aimed at Spanish-speaking audiences emerged and politicians realized that winning elections often required support from Hispanic voters.

With their new social and political clout, two-thirds of Hispanic adults have come to view their Hispanic origin as part of their race, according to a 2014 survey by the D.C.-based Pew Research Center. Hispanics "don't see themselves as white, black or any of the other races that have boxes on the census race question," Roth says.

In both the 2000 and 2010 censuses, over a third of those who selected a Hispanic ethnicity put themselves in the "some other race" category, making that ambiguous group the nation's third largest for both decades. Absent changes to how the race and ethnicity questions are asked, growth in the country's Hispanic population means "some other race" may become the nation's second largest racial group in 2020, the Census Bureau noted in a 2017 report.

For Hispanic people, at least, the ethnicity data can still reveal where such individuals might be experiencing discrimination — though confusion over the two questions could discourage people from completing the form, further increasing Hispanic undercounts, says sociologist Julie Dowling of the University of Illinois at Urbana-Champaign and chair of the Census Bureau's

National Advisory Committee on Racial, Ethnic and Other Populations.

Projections by the Urban Institute, a D.C.-based think tank, made while the current administration was considering adding a citizenship question to the census, showed that the 2020 count could miss 3.6 percent of Hispanics, or over 2.2 million people. Lingering fears over that question could still depress Hispanic participation, says the institute vice president, Rob Santos.

Undercounts translate to lost dollars. For instance, Child Trends, a nonprofit research organization, estimates that 37 states will lose out on funding from five federal child and family programs if there is an undercount of Hispanics on the 2020 census. Texas alone stands to lose $339 million to $1.4 billion annually.

Nonetheless, money still flows into Hispanic communities thanks to the ethnicity question. But for MENA communities — estimated at 3.7 million people according to the Arab American Institute — there is no equivalent channel. In recognition of those difficulties, the Census Bureau recommended adding race checkboxes for both Hispanic and MENA groups to the 2020 census. But the OMB, which must approve such changes, did not do so. (The OMB did not reply to a request for an interview and the Census Bureau did not make anyone available for an interview in the three months it took to report this story.)

One tweak made to the 2020 census could provide some information on MENA and other minority populations hidden within the broader categories, Dowling says. For the first time, those checking "black" or "white" can opt to write in their nationality of origin. But without a checkbox, the information will be in a less accessible form. "Somebody has to comb through that data," Dowling says.

A slippery sense of self

As minority groups fight for greater visibility, and the race question gets wound up in ideas about self-affirmation and group empowerment, the census data have been getting more difficult to decipher since the 1960 shift to self-identification.

With the power to check their own race box, many people previously identified as white have embraced a nonwhite or mixed-race identity. That's evident in the American Indian numbers. From 1890 to 1960, the American Indian population grew from 248,000 to 524,000, with an average annual growth rate of just 1.1 percent. But over the next several decades, and coinciding with the shift to self-identification, that population grew to almost 2 million by 1990 — with an average annual growth rate of 4.3 percent. That meteoric growth extends well beyond what is possible through births alone, Liebler says.

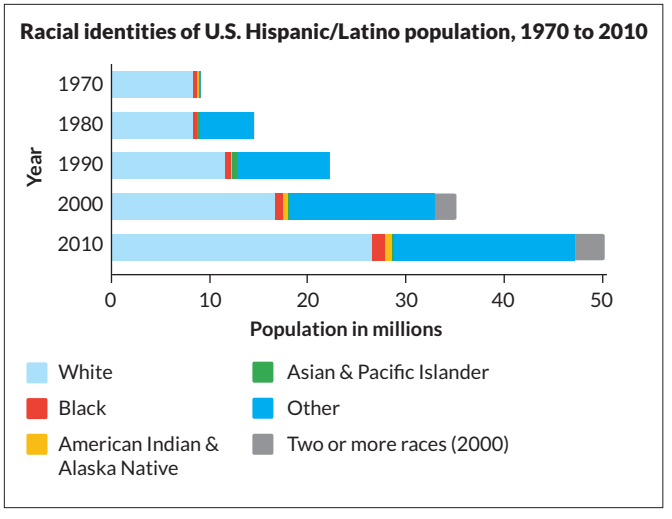
Working with collaborators at the Census Bureau, Liebler looked at changes to the American Indian category between the 2000 and 2010 censuses. Reporting in the April 2016 *Demography*, the team identified three "types" of American Indians — fewer than one-third reported American Indian on both censuses. The rest either alternated between single-race and mixed-race American Indian or added or dropped American Indian altogether from one census to another. That last category of people was less likely to report tribal affiliation or live in an American Indian area than those in the other two groups.

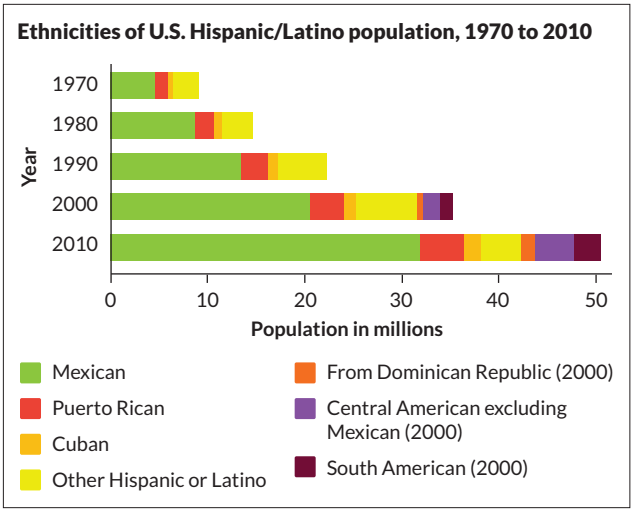
People with no connection to tribal groups who decide to check "American Indian" can have

Hispanic people feel "other"

In censuses since 1970, a growing percentage of people who choose an Hispanic/Latino ethnic identity are choosing "other" (left, darker blue) as their racial identity because they do not see themselves in the available race categories. At the same time, the options available for choosing their ethnic identity have expanded (right). Dates in parentheses show the year an option was added.

SOURCE: U.S. CENSUS





C. CHANG

real-life implications. For instance, American Indians suffer the lowest high school graduation rates of any group in the country, while the education profile of those "new" American Indians resembles that of whites. When education statistics coupled with census race data make it appear as if American Indians in many regions have become more educated, it implies that American Indians no longer require as much government support for education, Liebler says.

Genetic ancestry tests may be contributing to white people adopting American Indian and other minority identities, Roth's recent research suggests. From 2009 to 2010, Roth interviewed 100 individuals who purchased genetic tests and then re-interviewed 89 of those respondents after the 2010 census.

Reporting in the July 2018 *American Journal of Sociology*, Roth showed that 14 percent of participants changed their race in 2010 from that used in 2000 based on the test results. Though the study is small, the exploding popularity of such tests over the last decade (*SN: 6/23/18, p. 14*) means such tests could dramatically alter how people respond to the census race question.

But extensive interviews with the participants revealed striking group differences. While just 25 percent of black respondents chose a new racial or ethnic identity, about 40 percent of white respondents did so. What's more, white people often chose what new racial information to accept and what to discard. The ability to cherry-pick race is a uniquely white privilege, Roth says. Whites "can claim to be Native American ... or whatever they didn't know about before, and they can go to festivals and they can eat the food, but it's costless. It doesn't bring with it the same kind of discrimination that identity brings for somebody who is seen [by others] as a member of that group."

A more nuanced approach

What Roth is getting at is the idea that discrimination is more about how a person is seen by others than how they see themselves. A white-presenting individual who receives a genetic ancestry test result that reveals American Indian ancestral ties could check "white" and "American Indian" on the 2020 census, but that decision says nothing about the level of discrimination that person has experienced, Liebler says. And that decision makes it harder for policy makers to identify communities in need.

What's more, research over the last few decades has made clear that even for individuals within the same race, light-skinned individuals fare better in American society, receiving more lenient prison sentences and better job opportunities, than their dark-skinned counterparts. So even if "Hispanic," "MENA" or other race checkboxes were added, identifying that sort of discrimination within a group will remain impossible with the current race question.

"We need more than one measure of race," says sociologist Nancy López of the University of New Mexico in Albuquerque. One question should ask respondents to identify their own race so policy makers can continue to identify the country's changing social and political blocs. And another question should ask respondents to gauge how they appear to an outsider, such as an enumerator standing on their doorstep, census form in hand.

But don't expect to see changes to the race question anytime soon, Liebler says. "The push is entirely within the academic world. We've got no traction at all within the Census [Bureau]." Perhaps the place to tack on multiple race questions is on smaller federal surveys, such as those administered by health, education and housing agencies, Liebler says. "That seems plausible." ■

Race	Changed view of own identity after genetic ancestry testing
White (alone or in combination)	40.8%
Black (alone or in combination)	25.0%
Hispanic/Latino (alone or in combination)	31.6%
Asian (alone or in combination)	33.3%
American Indian (alone or in combination)	33.3%
All respondents	36%

Simple switch
After taking a genetic ancestry test, white respondents were most likely to change how they perceived their own race or ethnicity.
SOURCE: W.D. ROTH AND B. IVEMARK/*AM. J. SOCIOL.* 2018

Explore more

- Margo J. Anderson. *The American Census: A Social History. Second edition*. Yale University Press, 2015.
- Hephzibah V. Strmic-Pawl, Brandon A. Jackson and Steve Garner. "Race counts: Racial and ethnic data on the U.S. census and the implications for tracking inequality." *Sociology of Race and Ethnicity*, 2018.

The Challenge of a Country's Count

How the U.S. census measures race

By Betsy Ladyzhets

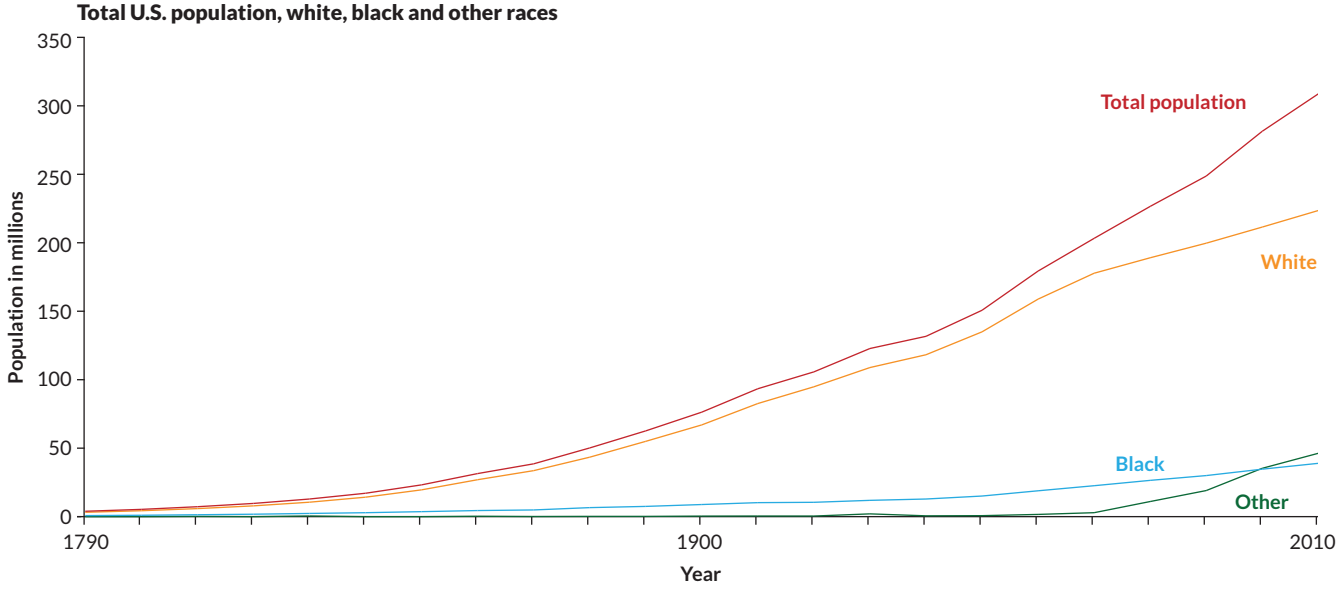
On the first Monday in August 1790, just over a year after the inauguration of President George Washington, America's first census marshals began knocking on doors. The new country's constitution decreed that each state would be represented in Congress "according to their respective numbers." A national enumeration was in order.

And so, marshals took to the streets with schedules, quill pens and ink in hand. The census intended to enumerate every person in the original 13 states, three districts (Kentucky, Maine and Vermont) and one western territory (Tennessee). The Northwest Territory and American Indian communities were left out. The marshals asked the head of each household to record his or her name and the size of the household, and then placed the residents into one of three racial categories: "white" people, "other free people" and "slaves."

That first census tallied 3.9 million residents, approximately the number of people living in Los Angeles today.

The U.S. population has expanded and diversified a great deal since that first count. And the categories the census uses to describe people have diversified as well. Still, the underlying purpose of the procedure, which happens every 10 years, remains the same: to determine each area's proportional representation in national and local politics and to distribute government funding for social services.

In that 1790 census, white people made up about 80 percent of the total population, enslaved black people represented 18 percent and other free people represented the remaining 2 percent. These three categories were the primary markers of racial difference in the population until 1860.



Official count From the first U.S. census to the most recent, the population grew from 3.9 million to 308.7 million. Because the race options do not include Hispanic and Middle Eastern or North African identities, many from these populations may identify as white on the census. SOURCE: U.S. CENSUS

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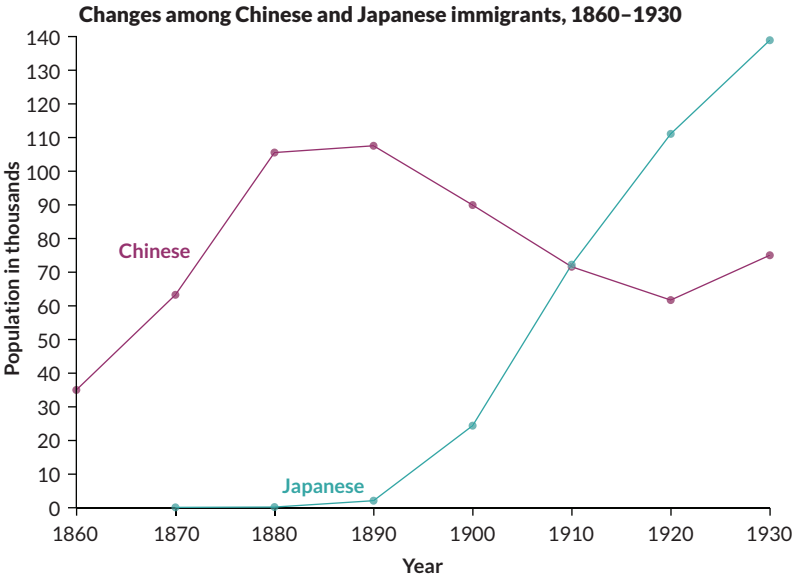
As retired census demographer Campbell Gibson notes in his online compilation, *American Demographic History Chartbook: 1790–2010*, racial categories used in the census tended to reflect social attitudes and political considerations. One such political consideration was built into the Constitution. To boost their representation in the House of Representatives, delegates from southern states wanted slaves to be counted with the free population. But northern states wanted the free population to be more heavily weighted. Delegates finally agreed on the Three-Fifths Compromise — each slave was counted as three-fifths of a person until the category "slave" was removed in 1860.

As additional race categories were added to the census in the 19th century, the trained enumerators who replaced the marshals determined race through observation. The power for defining the population was in the hands of the data collectors, rather than the people being counted.

The accuracy of historical census data fluctuated for minority groups as social power and political priorities changed. For example, the American Indian classification was first included in the 1860 census when California (1850), Minnesota (1858) and Oregon (1859) were entering the union and fighting for seats in the House of Representatives.

But the American bureaucracy was ill-equipped to count this population. In a local enumeration of New Mexico pueblos conducted from 1850 to 1870, for example, racial indications were often "unreliable," according to a history on the U.S. Census Bureau's website. One enumerator might use "non-White" to refer to a pueblo community member, another might refer to the same person as "Indian," and another might write in "copper." According to census data, the American Indian population (which, until 1890, did not include those living on reservations) went from 44,000 in 1860 down to 26,000 in 1870 and then up to 66,000 in 1880.

The census began to acknowledge members of other racial communities in the latter half of the 19th century as immigration from non-European countries increased. In 1860, the first year that a category for Chinese Americans was included, in California only, about 35,000 people were counted in that group. Many Chinese immigrants had arrived in California hoping to make their fortunes in the Gold Rush of 1849 or to help build the first transcontinental railroad. When "Chinese" appeared in the national census in 1870, the count was 63,000, which rose to 105,000 in 1880.



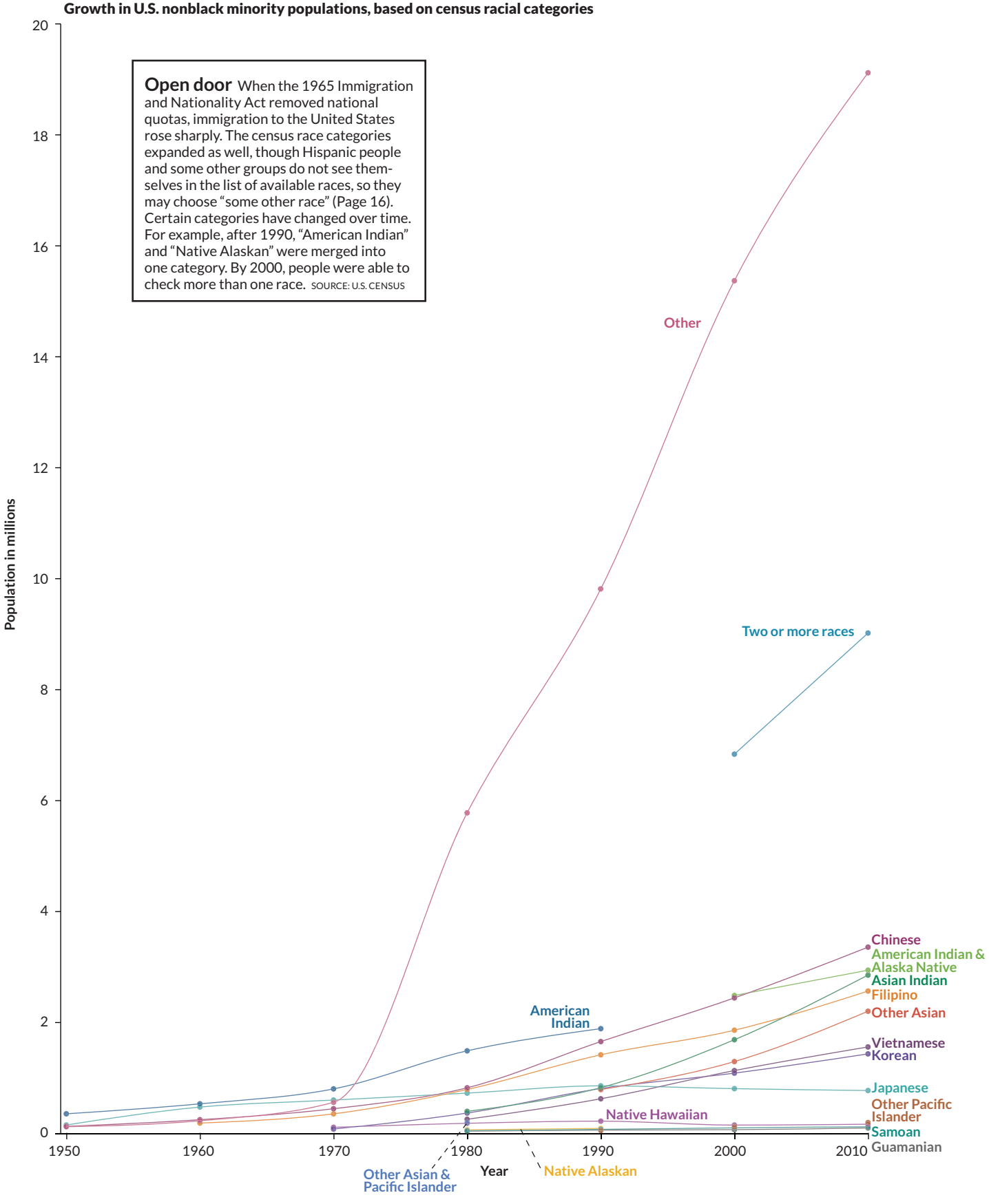
Early immigration control The number of Chinese people living in the United States was on an upward trajectory in the late 1800s, then declined with the passage of the 1882 Chinese Exclusion Act. Japanese immigrants did not face such constraints, so their numbers continued to rise. SOURCE: U.S. CENSUS

In 1882, however, Congress passed the Chinese Exclusion Act, prohibiting immigration from China for the next 10 years; further anti-Chinese policies and social norms led the Chinese-American population to drop below 100,000 until well into the 20th century. Immigration from Japan had fewer constraints in that time: The Japanese-American population grew from 148 people in 1880 to 138,834 in 1930.

Congress established national immigration quotas in 1921, limiting immigration from any given country to 3 percent of the population from that country already living in the United States. The next census after this policy was passed, in 1930, counted the country's existing immigrant population with more demographic categories than ever before, including categories for "Filipino" and other Asian minorities. This census was the first and last to specify "Mexican" as a race, enumerating about 1.4 million people in that category. However, the authors of the report on the 1940 census revised the population figures from 1930 to classify the Mexican population as white.

Immigration largely stagnated from the 1920s to the 1960s. But a game changer was the Immigration and Nationality Act of 1965. This law removed immigration quotas and created a seven-category preference system that prioritized relatives of U.S. citizens and professionals with specialized skills. Immigration rose sharply in the second

Growth in U.S. nonblack minority populations, based on census racial categories



half of the 20th century, with major waves coming from Asia, the Pacific Islands, Mexico and the Caribbean. The Filipino population, for example, jumped about tenfold from 180,000 in 1960 to more than 1.8 million in 2000. Census categories expanded with increasing diversity in that same time period.

On the eve of the new millennium in 2000, the number of racial categories the census used to delineate Americans had multiplied from the original three to 16, and respondents could choose from four Hispanic/Latino ethnic origin options. And for the first time, Americans could self-identify with more than one race.

Immigrants have driven America's population shifts, from Irish and Germans in the early 19th century to an ever-widening ethnic pool today. According to 2018 population estimates from the Census Bureau, there are 2.3 million foreign-born children and 15.9 million native-born children with immigrant parents living in the United States.

Thanks to this generation of new arrivals, first-generation immigrants and their children will represent 36 percent of the U.S. population in 2065, according to Pew Research Center projections reported in a 2015 study on the impacts of immigration on the American population.

The last few years have seen a shift in U.S. attitudes toward immigrants, with the current administration restricting immigration and creating a legal and political environment that could discourage immigrant families from participating in the census.

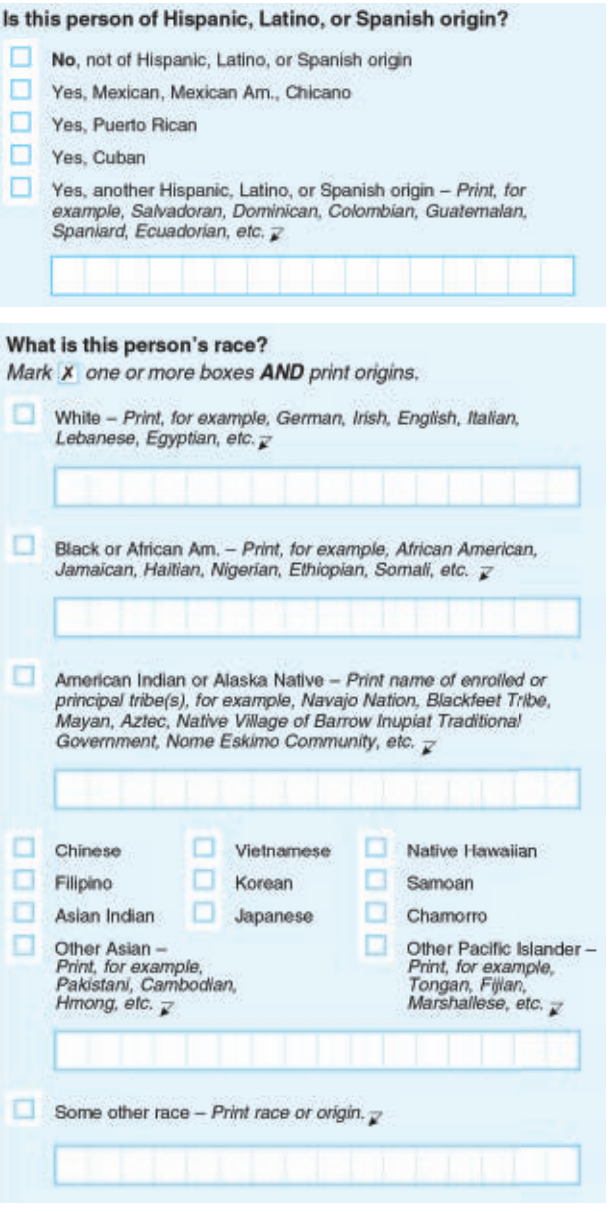
"If you're an immigrant living in the U.S. or trying to come to the U.S., the institutions have turned against you," says Austin Kocher, a faculty fellow at Transactional Records Access Clearinghouse, or TRAC, an organization based at Syracuse University in New York that compiles and disseminates data from the federal government.

According to TRAC's analysis, in the last three years, there have been spikes in the numbers of asylum cases that are denied, deportation cases that are considered and people detained by Immigration and Customs Enforcement.

Throughout U.S. history, immigration has always been tied to politics. As the 2020 census begins, it remains to be seen how the current political climate will affect who participates in this enumeration and how they will be counted. ■

Betsy Ladyzhets is a freelance science writer and data journalist based in Brooklyn, N.Y.

U.S. CENSUS



2020 census When people fill out the census this year, they will find one question about ethnic origin and one about race. Demographers would like to combine the race and ethnicity questions and add more categories.

Methodology: Historical U.S. census data used here and in the figures on Page 20 are from the Census of Population and Housing decennial reports, available at census.gov. Race categories are used as they appear in the census reports. Population data for different racial groups in different census years are sourced from the reports for those years, with two exceptions. Data for census years from 1790 through 1850 are sourced from the 1850 report, in which an extra analysis was done to reevaluate the older data; data for the Chinese, Japanese and "Other" populations for census years 1900 and 1910 are sourced from the 1920 report, as extra analysis was done in that year for Asian populations. 2010 census data are sourced from the 2010 decennial census tables PCT23, PCT11 and PCT5, available at data.census.gov.

Jennifer Doudna, one of the first researchers to develop CRISPR as a gene-editing tool, is interviewed in *Human Nature*.

FILM

The promise and peril of gene editing

Humans have been tinkering with the genes of plants and animals through selective breeding for millennia. But the ability to change our own DNA is something very new.

The gene-editing tool CRISPR offers the promise of correcting genetic typos that cause a range of diseases. The documentary *Human Nature* — which opened in select U.S. cities on March 13, with more to follow — introduces viewers to the technology. Graphics, archival footage and beautiful imagery help explain how scientists took a DNA-cutting enzyme and its guide molecule, which form the basis of bacterial immune systems, and transformed them into CRISPR/Cas9, often just called CRISPR. Pioneers of the technology, including Jennifer Doudna, Feng Zhang, George Church and Emmanuelle Charpentier, recount serendipitous discoveries and hard-won insights in the tale of CRISPR's development over several decades.

Human Nature
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At the heart of the film is an ethical discussion of whether to allow scientists to use CRISPR to make changes in eggs, sperm or embryos that could be inherited by future generations. In one scene, Russian President Vladimir Putin tells a group of young people that using CRISPR to make designer people could be more dangerous than the nuclear bomb. In a counterpoint, bioethicist Alta Charo of the University of Wisconsin Law School in Madison says such fears may be overblown.

The film is wide-ranging, but with a few glaring omissions. Most notably, in 2018, Chinese researcher Jiankui He announced that human babies had been born from CRISPR-edited embryos (*SN: 12/22/18 & 1/5/19, p. 20*). That announcement touched off a firestorm of controversy and debates among scientists about whether a self-imposed moratorium on heritable editing should be enacted. In December 2019, He was sentenced to three years in prison for forging documents to make it look as if he had approval from an ethics review board to do the work. The film's only reference to the event is a title card at the end that briefly lays out what happened and states, "It marked the first time in history that humans edited the genetic code of a future generation. This controversial experiment has intensified the global debate about where we, as a species, should draw the line."

He's announcement came as filming for *Human Nature* was wrapping up. It was too late "to add anything substantive" that would capture all the nuances of the case, says the film's director, Adam Bolt. The Chinese researcher's medical ethics violations might also have detracted from the film's exploration of whether to allow heritable editing in general, Bolt says. "We really wanted to make this film about the larger debate of 'should we do this.'"

The film also glosses over some potential environmental impacts. The idea of bringing back extinct animals (complete with a clip from *Jurassic Park*) is discussed. But the concept of gene drives, which has more immediate implications, is overlooked. Scientists envision using gene drives — a self-replicating, cut-and-paste version of CRISPR — to eliminate malaria-carrying mosquitoes or remove invasive species, for example. But by introducing harmful genes into wild organisms, gene drives have the potential to send entire species to extinction (*SN: 10/27/18, p. 6*). Granted, gene drives are hard to explain, but they deserve a mention.

Overall, *Human Nature* gets the science right, but its explanation of how CRISPR works is incomplete and may be misleading. The film shows an application of CRISPR that involves cutting out DNA containing a mutation and then pasting in a healthy copy of the gene. CRISPR theoretically could work that way, but in practice scientists have had trouble with this method. Instead, when CRISPR makes a cut, the ends of the cut DNA strands usually are haphazardly glued back together, making a mutation that can break a gene. That may not sound useful, but it is the basis for some possible treatments for genetic diseases (*SN: 8/31/19, p. 6*).

Human Nature is a good introduction for those wondering what the fuss over CRISPR is about. No film can capture the full breadth of the tool's reach. But by avoiding CRISPR babies, gene drives or even some of the challenges of treating diseases, the film paints a rosier picture than is warranted. Those topics deserve a sequel. — *Tina Hesman Saey*
Editor's note: Feng Zhang is a member of the Board of Trustees of Society for Science & the Public, which publishes Science News.

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SOCIETY UPDATE

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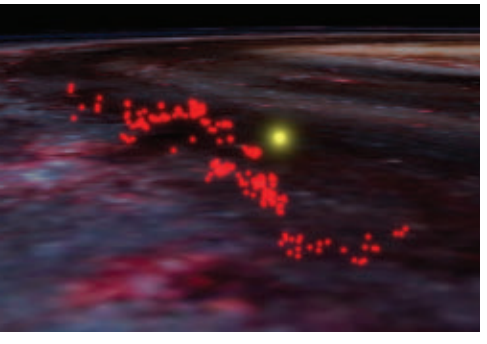
SOCIAL MEDIA

Gassy guffaws

Astronomers discovered a wave of star-forming gas clouds (red dots in the illustration below) next door to the sun (yellow dot), **Christopher Crockett** reported in "Giant gas wave lurks near solar system" (*SN: 2/1/20, p. 10*). Reader **Dalton Duncan** poked fun at the find on Facebook: "Turns out the Milky Way is lactose intolerant."



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Cellular hideout

*Delivering a tuberculosis vaccine intravenously instead of under the skin improved its effectiveness, **Tara Haelle** reported in "Old tuberculosis vaccine gets a boost" (SN: 2/1/20, p. 12).*

"My main takeaway from this article is that something as big as bacteria can get inside of a cell," reader **Mike Hamm** wrote. The article states that the bacteria that cause tuberculosis enter cells, but bacteria are typically much larger than viruses that infect cells, he noted. "So how does something as big as bacteria get through?"

Once in the lungs, TB bacteria infect cells called macrophages. These immune cells are part of the body's first line of defense against invaders. Macrophages typically swallow pathogens and destroy them in compartments called vacuoles, says epidemiologist **Tara Smith** of Kent State University in Ohio.

TB bacteria are swallowed by macrophages but aren't so easily destroyed. "Scientists are still trying to understand how TB bacteria manage to escape their death sentence," **Haelle** says. It's possible the bacteria trick macrophages into releasing a protein that reduces the cells' ability to fight infection.

Once TB bacteria escape death, they become executioners, somehow breaking up their macrophage prisons from within, **Haelle** says. Other types of cells rush to clean up the mess, forming clumps around the bacteria and macrophage debris. TB bacteria can live inside the clumps, which appear as lesions on the lungs, or break free to cause new infections.

Team effort

In his book The Crowd and the Cosmos, *astrophysicist Chris Lintott applauds the work of citizen scientists, **Erin Wayman** wrote in her review, which was headlined "An astrophysicist pays tribute to citizen science" (SN: 2/1/20, p. 29).*

The book review sparked warm memories for reader **Keith Greiner**. "I recall that my father, who graduated with a master's in chemistry in the 1930s, continued to contribute to his community as a scientist ... up until he passed away at the age of 108. I learned much from his postretirement investigations," **Greiner** wrote. He suggested that *Science News* report on how non-scientists can apply science in their lives. "Such an article would say to young readers, 'Even though your life may turn in many directions, your interest in science and mathematics can continue to grow.' "

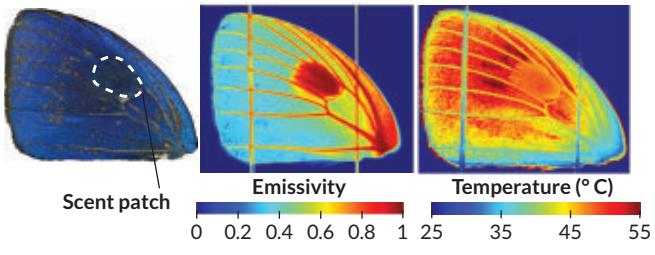
How butterfly wings take the heat

Delicate, thin butterfly wings can rapidly overheat in the sun. But living parts of the wing have a trick for staying cool.

New infrared images of butterflies (some shown above) reveal that living wing areas — including veins transporting insect blood, or hemolymph, and scent patches or pads that males use to release pheromones — can radiate more heat than nearby nonliving scales. That keeps the living areas cooler, researchers report January 28 in *Nature Communications*. Bright areas in the images correspond to higher heat release.

People may think that scale-covered butterfly wings are "like a fingernail, or a feather of a bird, or human hair — they are lifeless," says applied physicist Nanfang Yu of Columbia University. But wings are also equipped with living tissues crucial for survival and flight, and high temperatures will make the insect feel uncomfortable, he says.

Yu and colleagues used infrared cameras to measure wing emissivity and temperature at single-scale resolution



for more than 50 butterfly species. Emissivity is a measure of an object's ability to emit thermal energy and has a value from 0 to 1. Areas of high emissivity in a wing are better at radiating energy than low-emissivity zones, reducing temperatures of veins and scent patches (as shown for the species *Theritas hemon* directly above).

The team also determined how living wing tissue stays cool. Veins are covered with a thick layer of chitin, a component of an insect's exoskeleton, and scent patches and pads have tube-shaped nanostructures, plus the extra chitin. Thicker or hollow materials are better at radiating heat than thin, solid materials, Yu says. — *Erin Garcia de Jesus*

ALL: N. YU, CHENG-CHIA TSAI

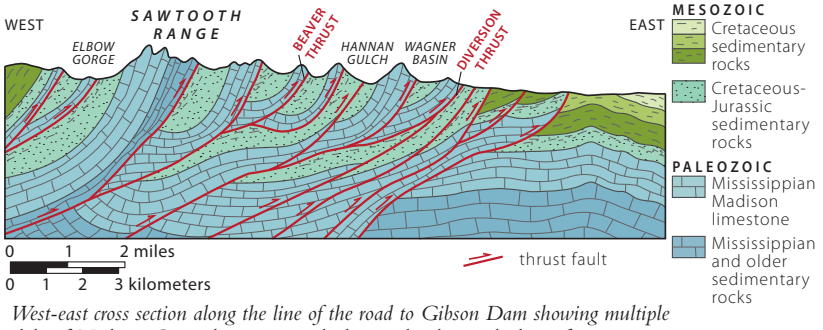
GEOLOGIC ROAD TRIP OF THE MONTH

SUN RIVER CANYON

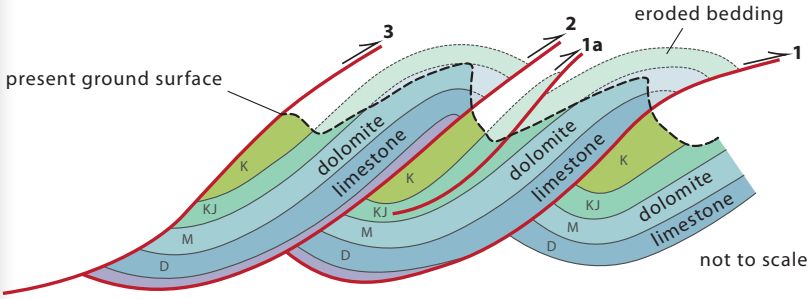
The best place in Montana to get a close roadside view of geologic structures in the Overthrust Belt is along the road that heads northwest from Augusta to Gibson Dam. Just outside Augusta, the road crosses a large moraine, its hummocky surface littered with erratic boulders. The moraine marks the edge of a glacier that poured out of the Sawtooth Range, spreading sluggishly across the plains east of the mountain front as a piedmont glacier.

The road enters the Sun River canyon through a narrow gorge eroded through the slab of Madison Group limestone that forms the steep front of the Sawtooth Range. It is the easternmost overthrust slab and lies on top of the Cretaceous sedimentary rocks exposed at the mouth of the canyon. The valley widens in the Wagner Basin west of the first slab of limestone, where less-resistant, younger rocks are exposed. Then the valley narrows again to pass through a second slab of Madison Group limestone that slid up and over the younger formations on another thrust fault. Another wide place in the valley, Hannan Gulch, marks the second outcrop of the same set of less-resistant, younger formations exposed in Wagner Basin.

View looking southwest over the entrance to Sun River canyon. Multiple slabs of cliff-forming Madison Group limestone were shoved northeastward over valley-forming Cretaceous shale during Sevier compression in Late Cretaceous time. —Courtesy of Rod Benson, Bigskywalker.com



West-east cross section along the line of the road to Gibson Dam showing multiple slabs of Madison Group limestone stacked on each other, with slices of younger Mesozoic formations sandwiched between them. Only thrust faulting on many surfaces can create such a bizarre arrangement of sedimentary layers.



Style of folds and thrust faults in Sun River canyon, west of Augusta. The numbers 1, 2, and 3 refer to the sequence of fault movements. D *stands for Devonian;* M, *Mississippian;* KJ, *Cretaceous-Jurassic;* K, *Cretaceous.* —Modified from Mudge, 1972

The road then passes through a third narrow gorge in the third overthrust slab of Madison Group limestone, which here anchors Gibson Dam. Dating of clays that formed from the heat generated during the thrust faulting indicates the faults were active 67 million years ago. Throughout the northern Montana Overthrust Belt, the ridges trend generally from north to south along the upturned edges of resistant limestone slabs, and the long valleys follow the less-resistant rocks between them.

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