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ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE ■ JUNE 19, 2021

In the Beginning

Research has expanded the possibilities of parenthood

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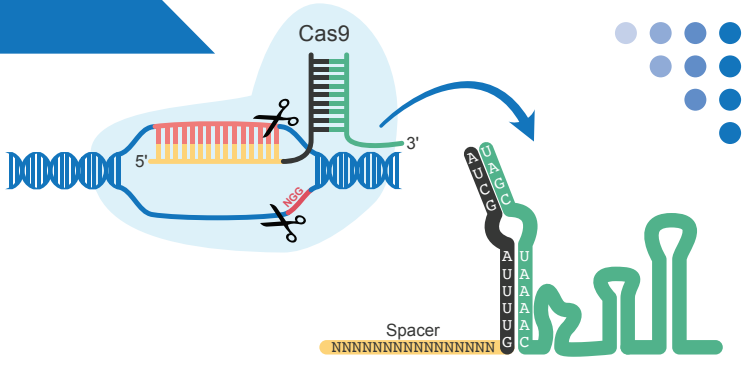

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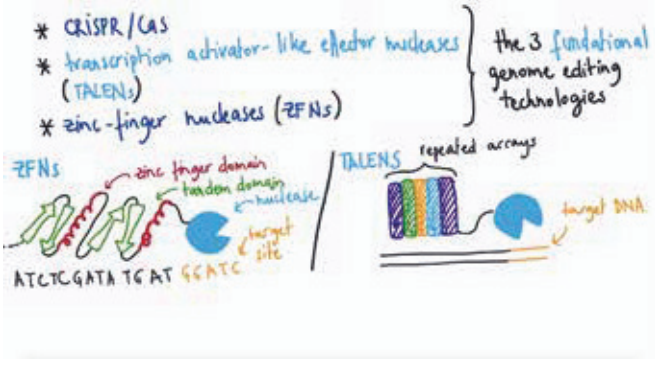

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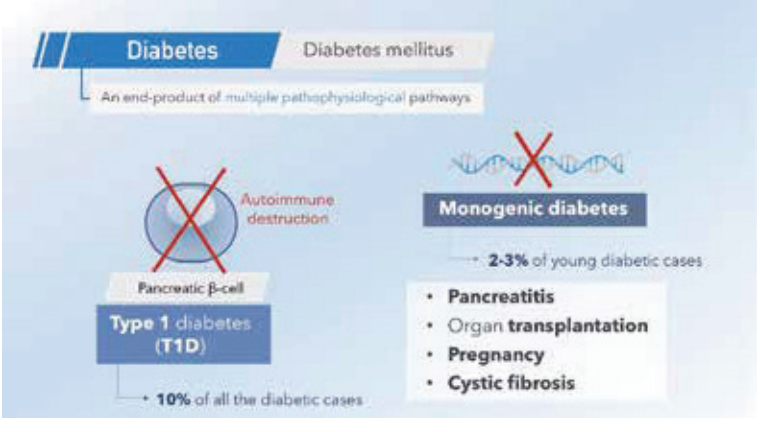

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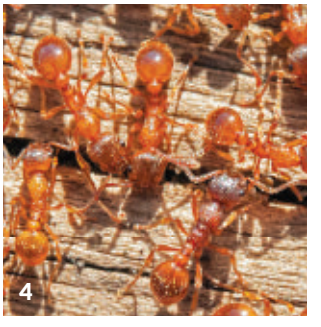
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Departments

COVER All it takes is the union of one egg and one sperm to get human life going. Sometimes that's easier said than done. *Nicolle Rager Fuller*

How test tube babies went mainstream

The notion that a baby's beginnings could transpire in a petri dish seems unremarkable today. But not even 50 years ago, researchers' efforts to devise technologies to allow infertile couples to have a baby sparked fierce opposition on multiple fronts, raising alarms around designer babies and eugenics. Scientists were afraid too.

"Sincere scientists ... really believed they might be creating monsters," says Robin Marantz Henig, who wrote this issue's cover story on the invention of assisted reproductive technologies, or ART (Page 16). The article is part of our Century of Science series exploring major scientific advances of the last 100 years and their impact on society.

Henig, author of the book *Pandora's Baby: How the First Test Tube Babies Sparked the Reproductive Revolution* and a contributor to *National Geographic* and the *New York Times Magazine*, explains just how hard it was for scientists to decipher the many steps to making a baby. The struggle included some wacky experiments, including loading sperm into a tiny chamber and inserting it in a volunteer's uterus to "prime" the sperm for action. It later turned out that no priming was necessary.

The debates over whether ART posed a threat to the future of humankind helped bioethics come of age, Henig says. With the rise of new reproductive technologies came the realization among scientists and regulators that braking mechanisms are necessary to give society time to assess potential impacts. We're seeing those concerns rise again around the very real notion of using CRISPR/Cas9 gene-editing technology on human embryos.

But after the first "test tube baby," Louise Brown, was born in July 1978, and more healthy babies followed, concern about ART quickly evaporated. "People were just so desperate," Henig says. These days having a child via in vitro fertilization is a routine option, and it has made parenthood possible for millions of people, including cancer patients, same-sex couples and single parents.

Henig imagines a future for reproductive technologies that might include creating egg and sperm cells by reprogramming a bit of one's own skin — no sex cells (or partners) needed. "You just take a sample of cells from someone when she's ready to have a baby," Henig speculates.

The "kids-from-my-skin" approach, if it comes to pass, could once again spark concerns about how science can rescript a process that is central to the essence of who we are. And if not this, then some other approach certainly will.

We'll continue to add new content to the Century of Science series through April 2022, with excerpts in the magazine and longer stories available at www.sciencenews.org/century. Online, you can explore a specific field of science, or compare across fields to see what was happening in, say, neuroscience, public health and quantum mechanics in the 1930s. We're also writing profiles of the people who made these discoveries possible, many of whom were underappreciated at the time. We're thoroughly enjoying this opportunity to celebrate *Science News'* centennial by exploring an extraordinary century of innovation and discovery, and we hope you are enjoying it too. — *Nancy Shute, Editor in Chief*

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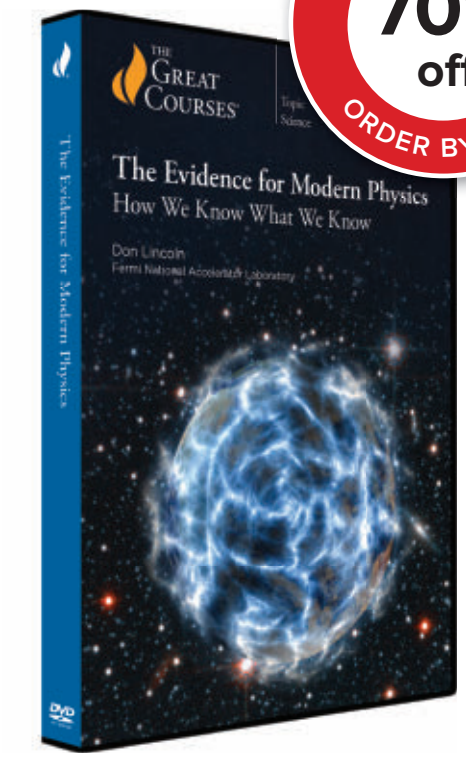

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Excerpt from the June 26, 1971 issue of *Science News*

50 YEARS AGO

What happened to UFOs?

Since 1968 the number of UFO sightings has dropped off, along with public interest in them.... [The] scientific debunking of the UFO phenomena and the subsequent, though not necessarily connected, decline in sightings presents an interesting behavioral pattern.... UFO reports usually run in five-year cycles and 1972 should be the start of another cycle.

UPDATE: Reports of unidentified flying objects have had their ups and downs. In 2020, people in the United States made more than 7,200 reports of UFO sightings — about 1,000 more than in 2019 and nearly 4,000 more than in 2018, according to the National UFO Reporting Center in Davenport, Wash. A quarter of last year's reports occurred in March and April, when much of the country was under lockdown due to the pandemic. Many of these UFOs turned out to be drones or satellites (*SN: 3/28/20, p. 24*). In late April, the Pentagon officially released naval footage of "unidentified aerial phenomena" that had been shared online, which may have primed some people to seek UFOs in their own backyards.

Ghost forests, such as this one in North Carolina, are coastal woodlands drowned by sea level rise. These arboreal cemeteries emit greenhouse gases from their soil and dead trees.

THE SCIENCE LIFE

Ecologists sniff out 'tree farts' to gauge the environmental impact of ghost forests

If a tree farts in the forest, does it make a sound? No, but it does add a smidge of greenhouse gas to the atmosphere.

Gases released by dead trees — dubbed "tree farts" — account for roughly one-fifth of the greenhouse gases emitted by skeletal, marshy forests along the North Carolina coast, researchers report May 10 in *Biogeochemistry*. While these emissions pale in comparison with other sources, an accurate accounting is needed to get a full picture of where climate-warming gases come from.

Ghost forests form when saltwater from rising sea levels poisons woodlands, leaving behind marshes full of standing dead trees. These phantom ecosystems are expected to expand with climate change.

To better understand how ghost forests pass gas into the atmosphere, ecologists Melinda Martinez and Marcelo Ardón went sniffing for tree farts in five ghost forests on the Albemarle-Pamlico Peninsula in North Carolina. "It's kind of eerie" out there, says Martinez, of North Carolina State University in Raleigh.

Ecologist Melinda Martinez uses a portable gas analyzer to measure "tree farts" in a ghost forest.

But Martinez ain't afraid of no ghost forest. In 2018 and 2019, she measured carbon dioxide, methane and nitrous oxide wafting off dead trees and soil using a portable gas analyzer that she toted on her back. "I definitely looked like a Ghostbuster," she says.

Ghost forest soil gave off most of the greenhouse gases. Each square meter of ground emitted an average of 416 milligrams of CO_2, 5.9 milligrams of methane and 0.1 milligrams of nitrous oxide per hour. Dead trees released an average of about 116 milligrams of CO_2, 0.3 milligrams of methane and 0.04 milligrams of nitrous oxide per square meter per hour — about one-fourth the soil's emissions.

Measuring greenhouse gases from the trees is "kind of measuring the last breath of these forests," says Ardón, also of North Carolina State University. The dead trees "don't emit a ton, but they are important" to a ghost forest's overall emissions.

Ardón coined the term tree farts to describe the dead trees' greenhouse gas emissions. "I have an 8-year-old and an 11-year-old, and fart jokes are what we talk about," he says. Just as microbes in the body cause human farts, microbes in ghost forest trees and soil emit greenhouse gases.

In the grand scheme of carbon emissions, ghost forests' role may be minor — tree farts have nothing on cow burps. But accounting for minor carbon sources is important for understanding the global carbon budget, Martinez says, so it would behoove scientists not to turn up their noses at ghost tree farts. — *Maria Temming*

BOTH: M. ARDÓN

TEASER

Fire ant chemicals might shoo spiders from a house's nooks and crannies

To make a spider flee, bring on the fire ants. Or rather, just their chemical signals.

In lab experiments, some spiders common in North American homes avoided building webs in chambers that recently housed European fire ants, researchers report May 19 in *Royal Society Open Science*. The ants probably left behind chemical traces, the researchers say, which could signal danger to the arachnids because ants sometimes feast on spiders. The reaction hints that the insects could be a source of natural spider-repelling chemicals.

"A lot of people are afraid of spiders, and there's nothing on the market that is reliable that keeps the spiders away," says arachnologist Andreas Fischer of Simon Fraser University in Burnaby, Canada.

Fischer and colleagues housed false black widow spiders (*Steatoda grossa*) in a glass container with three connected chambers. The arachnids were less likely to settle down in empty compartments that had once contained European fire ants (*Myrmica rubra*), an invasive species in North America. Other spider species — western black widow (*Latrodectus hesperus*), cross (*Araneus diadematus*) and hobo (*Eratigena agrestis*) — also were averse to the former fire ant chambers.

The finding is exciting but not ready for real-world use, Fischer says. "I really hope that people don't go out there and get European fire ants into their garden to get rid of spiders." The ants are aggressive, "horrendous pests," Fischer says, with stinging bites, and are tough to get rid of.

The team plans to pinpoint what chemical spooks the spiders, figure out if it can be made in the lab and make sure the potential spider repellent is not toxic or a homing beacon for fire ants. "That's the last thing we want, that we get rid of spiders but attract ants," Fischer says.
— Erin Garcia de Jesús

Chemicals left behind by European fire ants (shown in Finland) appear to drive away some spiders commonly found in North American homes. That finding could help researchers develop spider repellents.

FROM TOP: A. DETER-WOLF, T.M. PERES AND S. KARACIC/*JOURNAL OF ARCHAEOLOGICAL SCIENCE: REPORTS* 2021; © PENTTI KETOLA/INATURALIST (CC BY-NC 4.0)

THE –EST

Ancient Native Americans turned turkey bones into tattooing tools

This sharpened turkey leg bone is part of the oldest known tattoo kit.

Two sharpened turkey leg bones indicate that Native Americans used the items to make tattoos between about 5,520 and 3,620 years ago, microscopic studies suggest. These pigment-stained bones, unearthed from a man's burial pit at Tennessee's Fernvale site, are the world's oldest known tattooing tools, researchers report in the June *Journal of Archaeological Science: Reports*.

The find suggests that Native American tattoo traditions extend back more than a millennium earlier than previously thought. The oldest known tattoos belong to Ötzi the Iceman, who lived around 5,250 years ago in Europe (*SN: 1/23/16, p. 5*). But scientists haven't found the tools used to make them.

Damage on and near the tips of the turkey leg bones resembles a distinctive wear pattern previously observed on tattooing tools made from deer bones, the team says. Turkey wing bones found in the grave display wear and pigment residues that likely resulted from tattooing, while pigment-stained seashells may have held solutions into which tattooers dipped those tools. *— Bruce Bower*

SCIENCE STATS

Record-breaking gamma rays hint at violent environments in space

The cosmos keeps outdoing itself. Scientists have spotted extremely energetic light from space at higher energies than ever before. The Large High Altitude Air Shower Observatory, or LHAASO, in China's Sichuan province detected more than 530 gamma rays with energies above 0.1 quadrillion electron volts, researchers report May 17 in *Nature*. The highest-energy gamma ray detected was about 1.4 quadrillion electron volts. For comparison, protons in the largest accelerator on Earth, the Large Hadron Collider, reach mere trillions of electron volts. Previously, the most energetic gamma ray known had just under a quadrillion electron volts (*SN: 2/27/21, p. 12*). Possible sources of such energetic light are turbulent remains of exploded stars and regions where massive stars form. *— Emily Conover*

1.4
quadrillion electron volts
The highest amount of energy yet detected for light

BODY & BRAIN

Gene therapy may restore vision

Light-activated proteins helped a man see objects

BY TINA HESMAN SAEY

A new type of gene therapy that rewires nerve cells in the eye has given a man who is blind some limited vision.

The 58-year-old man has a genetic disease called retinitis pigmentosa, which causes light-gathering cells in the retina to die. Before the treatment, known as optogenetic therapy, the man could detect some light but couldn't see motion or pick out objects. Now he can see and count objects, and he even reported being able to see the white stripes of a pedestrian crosswalk, researchers report May 24 in *Nature Medicine*. The man's vision is still limited and he must wear special goggles that send pulses of light to the treated eye.

"It's exciting. It's really good to see it working and getting some definite responses from patients," says David Birch, a retinal degeneration expert at the Retina Foundation of the Southwest in Dallas. Birch has conducted clinical trials of other optogenetic therapies, but was not involved in this study.

A man who is blind saw objects thanks to gene therapy and goggles. A cap on his head showed that signals from the eye reached the brain.

STREETLAB/INSTITUT DE LA VISION, J.-A. SAHEL *ET AL/NATURE MEDICINE* 2021

Researchers have been working for more than a decade on experimental optogenetic therapies to restore vision to people with degenerative eye diseases, such as retinitis pigmentosa (*SN: 5/30/15, p. 22*). The therapies use a light-sensitive protein to make nerve cells fire off signals to the brain when hit with a certain wavelength of light.

Optogenetic therapy is different from traditional gene therapy, which replaces a faulty version of a gene with a healthy one. It is also different from gene editing, which uses molecular tools such as CRISPR/Cas9 to fix disease-causing variants of particular genes. In 2017, the U.S. Food and Drug Administration approved a traditional gene therapy that treats a rare form of inherited blindness caused by mutations in the *RPE65* gene. Other researchers are conducting clinical trials of gene-editing treatments to correct a single mutation that causes an inherited form of blindness called Leber congenital amaurosis 10 (*SN: 8/31/19, p. 6*).

Those therapies may halt or slow progression of degenerative eye diseases, but don't help people who have already lost vision, says Botond Roska, a neuroscientist and gene therapist at the Institute of Molecular and Clinical Ophthalmology Basel and the University of Basel in Switzerland. Traditional gene therapy and gene editing also target only certain genes, but retinitis pigmentosa can be caused by changes in any one of more than 50 genes. Optogenetic therapy may help people who have lost their sight from diseases regardless of the gene changes that cause those diseases. Such diseases potentially include macular degeneration, which affects millions of people worldwide.

Earlier versions of optogenetic therapy used a protein called channelrhodopsin-2 from algae to make nerve cells respond to light. That protein requires lots of bright blue light to work. "It's like staring at the sun in the desert," says José-Alain Sahel, an ophthalmologist and retinal specialist at the University of Pittsburgh and Sorbonne University in Paris. The level of light needed to turn the protein on could kill any remaining cells in the retina. So Sahel, Roska and colleagues developed a therapy using a light-sensing protein that responds to amber light, which does less damage to cells than blue or green wavelengths.

The team used a virus to deliver instructions for making the protein to a layer of nerve cells called ganglion cells in one of the man's eyes.

The retina has three layers: Light-gathering rods and cones are at the back of the retina. Those photoreceptor cells are the first to die in retinitis pigmentosa. Next comes a layer of nerve cells known as bipolar cells. They process visual information and pass signals on to ganglion cells in the third layer. The ganglion cells fire messages to visual centers in the brain.

Some researchers, including Sahel and Roska's team, are also experimenting with inserting optogenetic proteins into cones that have lost function but haven't died, bipolar cells or other nerve cells. But ganglion cells are the easiest target, Roska says. They can be reached by simply injecting the virus into the eye. And ganglion cells stick around long after rods, cones and bipolar cells have died.

The treated man cannot see without special goggles that send pulses of amber light to his eye. That is because ganglion cells usually respond to changes in light. If the light is constant, the cells don't continue to fire, so pulses are needed, Roska says.

In addition, while normal vision can work in everything from dim starlight to the sunniest day on the beach, the optogenetic proteins operate under a very limited range of light levels, says Zhuo-Hua Pan, a vision neuroscientist at Wayne State University in Detroit. The goggles use digital camera technology to automatically adjust light levels sent to the man's eye. Other people who get

optogenetic therapy will also probably need to wear goggles to help process visual information before it goes to the brain, Pan and Birch say.

With the goggles sending pulses of light to the man's treated eye, he could see and recognize objects such as a book, cups and a bottle of hand sanitizer on a table.

The researchers demonstrate that the goggles are necessary for the man to see the objects. But to really show the therapy improved vision, the researchers would need to see if shining the amber light into his eye *before* the therapy would be enough to allow him to see, says Sheila Nirenberg, a neuroscientist at Weill Cornell Medicine in New York City and founder of Bionic Sight, a company that is using a different optogenetic protein to treat blindness. If so, that would suggest that just bright light, not the therapy itself, is behind the improvement in vision.

Bionic Sight reported in a news release in March that in a clinical trial, people who are blind could see light and motion after treatment. The results are preliminary — a full report may be a year or more away, Nirenberg says.

Another company, Nanoscope Technologies in Bedford, Texas, reported in a presentation at a virtual meeting of the American Academy of Ophthalmology in November that its optogenetics treatment had also restored limited vision to some people with retinitis pigmentosa. But the company has not yet released a full accounting of the data. "Without the details it's difficult to evaluate," Pan says.

The report in *Nature Medicine* is encouraging because it shows some details, Pan says, although he wants to know more about what the patient can see outside of the lab. Still, Pan is pleased that the work is yielding results. "We've been waiting to hear this for many years."

Sahel and Roska stress that the therapy is not a cure for blindness. "For now, all we can say is that there is one patient ... with a functional difference," Roska says. Sahel adds, "It's a milestone on the road to even better outcomes." ■

SHERRY GALEY/MOMENT OPEN/GETTY IMAGES PLUS

Northern Canada (shown) is one region that could see an increase in fires that winter underground.

EARTH & ENVIRONMENT

'Zombie' fires could become common

Climate change might fuel more hibernating forest infernos

BY JONATHAN LAMBERT

Winter kills most forest fires. But in boreal woods encircling the far north, some fires just don't die.

The first broad look at overwintering "zombie" fires reveals that these rare occurrences can flare up the year after warmer-than-normal summers, scientists report in the May 20 *Nature*. As climate change accelerates in boreal forests, the frequency of zombie fires could rise. That could exacerbate warming by releasing greenhouse gases from the region's soils, which house an outsized amount of carbon (*SN: 4/13/19, p. 16*).

Zombie fires hibernate underground. Blanketed by snow, the fires survive on carbon-rich peat and boreal soil and move slowly — less than 500 meters over the winter. Come spring, the infernos reemerge near the forest they previously charred, burning fresh fuel well before fire season starts. Until now, zombie fires were known mostly from firefighter anecdotes.

Strange coincidences spotted in satellite images, however, got the attention of Rebecca Scholten and colleagues. "My adviser noticed that some years, new fires were starting close to the previous year's fire," says Scholten, an earth systems scientist at Vrije University Amsterdam. This is unusual, she says, since lightning or human activity usually spark boreal fires. Local fire managers confirmed that the fires were the same, prompting the researchers to wonder just how often fires overwinter.

Combining firefighter reports with satellite images of Alaska and northern Canada captured from 2002 to 2018, the team looked for blazes that started near scars left the previous year and that began before midsummer, when lightning-sparked fires usually occur. Zombie fires accounted for just 0.8 percent of the total area burned by forest fires over that time period. But there was variability. In 2008, one zombie fire in Alaska burned approximately 13,700 hectares, about 38 percent of all burned areas that year in that state. Zombie fires were more likely to occur, and burn larger swaths of land, when the previous summer was warm, allowing fires to reach deeper into the soil.

The findings are a welcome advance, says geographer Jessica McCarty of Miami University in Oxford, Ohio. Understanding when zombie fires are more likely to occur could help firefighters protect landscapes that house a lot of climate warming gases. While "areas we thought were fire resistant are now fire prone" due to climate change, McCarty says, better fire management can make a difference. "We're not helpless." ■

BODY & BRAIN

Psychedelic drug eases severe PTSD

MDMA and talk therapy ousted the diagnosis in some people

BY LAURA SANDERS

The key ingredient in the illicit drug known as Ecstasy may offer profound relief from post-traumatic stress disorder. When paired with intensive talk therapy, MDMA eased symptoms in people who had struggled with severe PTSD for years, researchers report in a new study.

"This is a big deal," says clinical psychologist Steven Gold, a professor emeritus at Nova Southeastern University in Fort Lauderdale, Fla. "All other things being equal, the use of psychedelic medication can significantly improve the outcome."

The preliminary findings, published May 10 in *Nature Medicine*, offer hope to the millions of people worldwide who have PTSD. Antidepressants such as Zoloft and Paxil are often prescribed, but the drugs don't work for an estimated 40 to 60 percent of people with PTSD.

Ninety people participated in the new study, which took place at 15 clinical sites in the United States, Canada and Israel. All participants received 15 therapy sessions with therapists, all of whom were trained to guide people as they experienced the drug. Half of the participants received MDMA in three eight-hour sessions; the other half received placebos during three eight-hour sessions.

MDMA, true to its nickname Ecstasy, evokes feelings of bliss and social connectedness. The participants took the drug (or the placebo) while wearing eye covers and listening to music, and occasionally talking with their therapist about their experience.

On average, the participants improved by the end of the 18-week trial, showing fewer PTSD symptoms such as unwanted, intrusive memories. But the benefits were far greater for people who took the drug than for people who took a placebo. By the end of the trial, 67 percent of participants in the MDMA group had improved so much that they no longer qualified as having a PTSD diagnosis. Among participants in the placebo group, 32 percent no longer met the criteria for PTSD at the end of the study. Those evaluations came from independent clinicians who assessed participants without knowing who had taken the drug.

Many people in the trial had been living with severe PTSD for years. "Typically, we see PTSD as a disorder for life. Now, we may begin to let that go," says Eric Vermetten, a psychiatrist at the Leiden University Medical Center in the Netherlands who works with veterans and members of the military with PTSD and was not involved in the study.

It's not clear exactly how MDMA changes the brain. Some imaging studies suggest that the drug dampens activity in the amygdala, a brain structure involved in fear. Other results from mice hint that MDMA may open a window of heightened social learning, a scenario that could strengthen the relationship between a patient and a therapist.

The new study included weeks of talk therapy. Those sessions took place before, during and after MDMA sessions. Talk therapy required hard emotional work from participants, says study coauthor Amy Emerson. MDMA "is not a magic pill," she says. The study was funded by the nonprofit group Multidisciplinary Association for Psychedelic Studies, or MAPS. Emerson is the CEO of MAPS Public Benefit Corporation in San Jose, Calif., which organized the trial.

Over three-quarters of the participants in the trial were white. Without a more diverse group of people in such studies, it's not clear whether therapy with MDMA would yield similar effects more generally, Gold says. Researchers are following the health of the participants in the new study to see whether the improvements last.

Another clinical trial comparing MDMA's effects on PTSD symptoms with a placebo is in the works, Emerson says, as well as expanded use of MDMA in clinics.

For now, the research is complicated by restrictions on MDMA, which remains an illicit drug in the United States. "There are a lot of barriers to break down related to this treatment," Emerson says. "And there's a lot of hope." ■

Therapists work with a participant during a trial to determine if MDMA, the key ingredient in the drug Ecstasy, can ease symptoms of post-traumatic stress disorder. A majority of participants who received the drug no longer qualified for a PTSD diagnosis after the trial ended.

MULTIDISCIPLINARY ASSOCIATION FOR PSYCHEDELIC STUDIES

BODY & BRAIN

Brain training may not sharpen minds

Playing games didn't boost mental abilities in a real-world test

BY JACKIE ROCHELEAU

It's an attractive idea: By playing problem-solving, matching and other games online for a few minutes a day, people could improve reasoning, verbal skills, memory and other mental abilities. But whether such brain training delivers on those promises is unclear (*SN: 4/1/17, p. 7*; *SN: 6/15/13, p. 12*).

"For every study that finds some evidence, there's an equal number of papers that find no evidence," says cognitive neuroscientist Bobby Stojanoski of Western University in London, Ontario.

Now, in one of the biggest real-world tests of these online brain training programs, Stojanoski and colleagues pitted more than 1,000 people who regularly use brain trainers against around 7,500 people who don't. There was little difference between how the groups performed on a series of tests of thinking abilities, suggesting that brain training doesn't live up to its name, the team reports in the April *Journal of Experimental Psychology: General*.

"They put brain training to the test," says cognitive aging scientist Elizabeth Stine-Morrow of the University of Illinois at Urbana-Champaign. While the study doesn't show *why* brain trainers aren't seeing benefits, it does show there is no link "between the amount of time spent with the brain training programs and cognition," Stine-Morrow says.

The team recruited 8,563 volunteers globally through the Toronto-based company Cambridge Brain Sciences, which provides assessments to measure healthy brain function. (While several researchers are affiliated with Cambridge Brain Sciences, the company didn't receive funding for the study.) Participants filled out an online survey about their training habits, opinions about training benefits and which program they used. One thousand nine participants reported using training programs for about eight months, on average, though durations ranged from two weeks to around five years.

All participants then completed 12 cognitive tests assessing memory, reasoning and verbal skills. They faced memory exercises, pattern-finding puzzles, strategy challenges and spatial reasoning tasks including mentally rotating objects.

Brain trainers on average had no mental edge over the other group in memory, verbal skills and reasoning. Even among the most dedicated brain trainers, who had used training programs for at least 18 months, brain training didn't boost thinking abilities above the level of people who didn't use the programs.

That's not because brain trainers started with poorer function and then improved. Participants who had trained for less than a month, and presumably wouldn't have yet reaped significant benefits from the programs, performed no better than people who didn't train at all.

"We were unable to find any evidence that brain training was associated with cognitive abilities," Stojanoski says. That held true whether the team analyzed participants by age, program used, education or socioeconomic status — all were cognitively similar to the group that didn't use the programs.

While it's possible to improve mental abilities, Stine-Morrow advocates practicing those skills in real-life situations. "That's a much better use of one's time than sitting at a computer and doing little tasks." ■

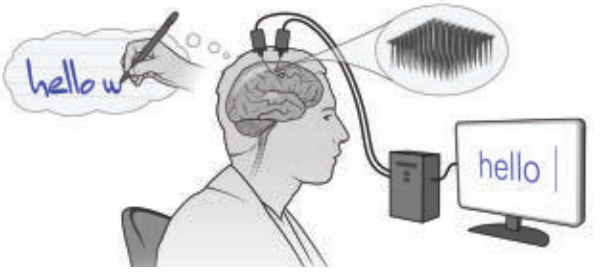
BODY & BRAIN

Implants turn thoughts into text

Electrodes in the brain of a man who is paralyzed turned his imagined handwriting into words typed on a screen. The translation from brain to text may ultimately point to ways to help people with disabilities like paralysis communicate using just their thoughts.

Two grids of tiny electrodes, implanted on the surface of a 65-year-old man's brain, registered electrical activity in the part of the brain that controls hand and finger movements. Although the man was paralyzed from the neck down due to a spinal cord injury, he imagined writing letters softly with his hand. Scientists used an algorithm to figure out the neural patterns that went with each imagined letter and transform those patterns into text on a screen (illustrated at right).

The man produced 90 characters, or 15 words, per minute with brain activity alone, neuroengineer Krishna Shenoy of Stanford University and colleagues report in the May 13 *Nature*. On average, that's about as fast as people around the man's age type on smartphones.



F.R. WILLETT *ET AL*/*NATURE* 2021, ERIKA WOODRUM

The thought-to-text system worked long after the injury. "The big surprise is that even years and years after spinal cord injury, where you haven't been able to use your hands or fingers, we can still listen in on that electrical activity. It's still very active," Shenoy says.

Thought-powered communication is still in its early stages. Research with more volunteers is needed, Shenoy says. The researchers plan to test the system with a person who has lost the ability to move and speak. — *Anushree Dave*

HUMANS & SOCIETY

Minor warfare dates to the Stone Age

Hunter-gatherers launched brutal raids at least 13,400 years ago

BY BRUCE BOWER

More than 8,000 years before the rise of Egyptian civilization, hunter-gatherers went on the attack in the Nile Valley.

Skeletons of adults and a teenager excavated in the 1960s in Sudan at an ancient cemetery known as Jebel Sahaba display injuries incurred in repeated skirmishes, raids or ambushes, say paleoanthropologist Isabelle Crevecoeur and colleagues. The site, which dates to between 13,400 and 18,600 years ago, provides the oldest known evidence of regular, small-scale conflicts among human groups, says Crevecoeur, of the University of Bordeaux in France.

People buried at Jebel Sahaba don't show signs of having fought in a one-time battle. Instead, they participated in an early form of sporadic warfare, the team concludes May 27 in *Scientific Reports*.

"Repeated violent episodes were probably triggered by well-recorded environmental changes" around the time people were buried at Jebel Sahaba, Crevecoeur says. Signs of human activity declined sharply in the Nile Valley between around 126,000 and 11,700 years ago. Toward the end of that span, hunter-gatherers occupied floodplains in what's now southern Egypt and northern Sudan. As the Ice Age waned, a fluctuating climate contributed to declines of prime fishing and hunting spots. Competition for those resources probably triggered fighting among regional groups, the researchers suspect.

Ancient people carefully buried their dead at Jebel Sahaba. "So amidst the apparent hardship, amidst the apparent violence and tragedy, we still see humanity here," says bioarchaeologist Christopher Stojanowski of Arizona State University in Tempe.

Out of 61 Jebel Sahaba skeletons held at the British Museum in London, 41 have at least one injury, Crevecoeur and colleagues report. Most of that damage was caused by stone spears, arrow points or close combat, the team says. Microscopic analysis also shows that 16 individuals had both healed and unhealed injuries, suggesting they had experienced repeated violent incidents during their lives.

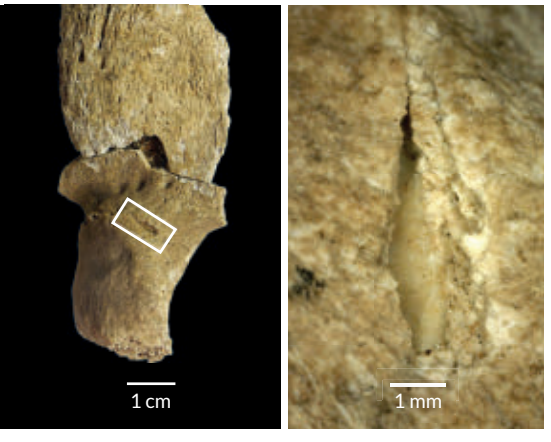
Men, women and children from Jebel Sahaba display similar types of weapon wounds, in comparable proportions. That injury pattern more likely arose from periodic raids rather than a single battle, in which the dead would have been mainly male fighters, the team says.

"Violence towards this community was truly extensive and indiscriminate in terms of age and sex," says biological anthropologist Marta Mirazón Lahr of the University of Cambridge.

Researchers have long debated whether warfare originated among Stone Age hunter-gatherers or among state societies within the last 6,000 years (*SN: 8/10/13, p. 10*). Isolated fossil cases of violence and murder date back to around 430,000 years ago (*SN: 6/27/15, p. 14*).

It's hard to estimate precisely the frequency of attacks among ancient hunter-gatherers in Africa and elsewhere, says archaeologist Mark Allen of California State Polytechnic University, Pomona. The new findings suggest that resource competition has long sparked raiding among these groups, he says. ■

A puncture, shown in the box at left and close-up at right, in an adult's left hip bone from the ancient Jebel Sahaba cemetery in Sudan contained a piece of a stone point.



ATOM & COSMOS

Galactic arms lob fast radio bursts

Some blasts may hail from young stars of spiral galaxies

BY LISA GROSSMAN

Five brief, bright blasts of radio waves from deep space now have precise addresses.

The fast radio bursts, or FRBs, come from the spiral arms of their host galaxies, researchers report in a study to appear in the *Astrophysical Journal*. The proximity of the FRBs to sites of star formation bolsters the case for run-of-the-mill young stars as the origin of these elusive, energetic eruptions.

"This is the first such population study of its kind and provides a unique piece to the puzzle of FRB origins," says Wen-fai Fong, an astronomer at Northwestern University in Evanston, Ill.

FRBs typically last a few milliseconds and are never seen again. Because the bursts are so brief, it's difficult to nail down their precise origins on the sky. Although astronomers have detected about 1,000 FRBs since the first one was reported in 2007, only 15 or so have been traced to a specific galaxy.

The first FRB scientists traced to its source came from a small, blobby dwarf galaxy with a lot of active star formation (*SN: 2/4/17, p. 10*). The fact that a single source sent off repeated blasts is an unusual feature and helped astronomers localize the FRB's host galaxy.

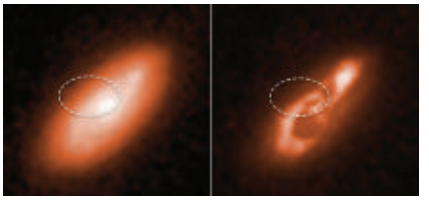
"After that, a lot of people thought, well, maybe all FRB hosts are like this," says astronomer Alexandra Mannings of the University of California, Santa Cruz. Then a repeating burst was tracked back to a spiral galaxy like the Milky Way (*SN: 2/1/20, p. 9*). And a one-off burst was localized to a massive disk-shaped galaxy, also the size of the Milky Way. More FRBs from spiral galaxies followed.

Mannings, Fong and colleagues thought they could learn more about FRB sources by localizing the blasts' origins even more precisely. Using the

Hubble Space Telescope, the team took high-resolution images of eight galaxies that were already known to host FRBs, then overlaid the FRBs' positions onto the images. The five FRBs that came from clearly defined spiral galaxies all lay on or close to the galaxies' spiral arms. Those arms had not been visible in images from ground-based telescopes. The other three host galaxies had inconclusive shapes, Fong says.

Different parts of spiral galaxies tend to host different types of stars. The bright spiral arms tend to mark sites where new stars are being born, while the older and dimmer stars have had time to drift away from the arms into the rest of the galaxy. So figuring out which galactic neighborhoods FRBs call home can reveal a lot about what kind of objects they come from.

Being on or close to the arms suggests the FRB locales have a fair amount of star formation, but they're not the brightest and most active parts of the galaxies, Fong says. That suggests



Processing a space telescope image of a galaxy (left) pinpointed the origin (oval) of a fast radio burst to one of the galaxy's spiral arms (right).

FRBs originate from ordinary young stars — not the youngest, most massive stars that occupy the brightest knots in the spiral arms, but not the oldest and dimmest stars that have drifted away from their homes, either.

That finding, Mannings says, is consistent with the idea that FRBs come from highly magnetized stellar corpses called magnetars (*SN: 7/4/20 & 7/18/20, p. 12*). There are several ways to produce magnetars from ordinary stars. One slow way involves waiting billions of years for a pair of ordinary stars to turn into neutron stars and then collide (*SN: 12/19/20 & 1/2/21, p. 10*). Or there's a fast way, which follows the death of a single massive star. Based on their locations, it seems like FRBs might come from an in-between process, like the death of a not-so-massive star that produces a magnetar, Mannings says.

"The fact that FRBs are found to be pretty close to, if not on, the spiral arm, near to these star-forming regions, that can give us a better idea of what the timeline is like for the progenitor," whatever created the FRB, Mannings says. "And if it is a magnetar, it lets us know that it's not through the delayed channel, like a neutron star merger."

The finding doesn't entirely solve the mystery of where FRBs come from, says astrophysicist Emily Petroff of McGill University in Montreal and the University of Amsterdam. But it does offer a broader picture of FRB host galaxies. "FRBs keep throwing a lot of surprises at us, in terms of what they look like, where they're found, how they repeat," Petroff says. The next step, of course, is to find more FRBs. ■

NASA, ESA, A. MANNINGS/UNIV. OF CALIFORNIA SANTA CRUZ, W.-F. FONG/NORTHWESTERN UNIV., ALYSSA PAGAN/STSCI

MATTER & ENERGY

Atomic bomb test made a quasicrystal

Debris contains a material with an odd, nonrepeating structure

BY EMILY CONOVER

In an instant, the bomb obliterated everything. The tower it sat on and the copper wires strung around it: vaporized. The desert sand below: melted.

In the aftermath of the first test of an atomic bomb, in July 1945, all this debris fused together, leaving the ground of the New Mexico test site coated with a glassy substance now called trinitite. High temperatures and pressures helped forge an unusual structure within one piece of trinitite, in a grain of the material just 10 micrometers across — a bit longer than a red blood cell.

That grain contains a rare form of matter called a quasicrystal, born the moment the nuclear age began, scientists report in the June 1 *Proceedings of the National Academy of Sciences*.

Normal crystals are made of atoms locked in a lattice with a structure that repeats in a regular pattern. Quasicrystals have a structure that is orderly like a normal crystal but doesn't repeat. This means quasicrystals can have properties that are impossible for normal crystals.

First discovered in the lab in the 1980s, quasicrystals also appear in nature in meteorites (*SN: 1/21/17, p. 16*). The quasicrystal from the New Mexico test site is the oldest one known that was made by humans.

Researchers found a quasicrystal in red trinitite that formed from melted sand and debris during the Trinity atomic bomb test.

Trinitite takes its moniker from the nuclear test, named Trinity, in which the material was created in abundance (*SN: 4/10/21, p. 16*). "You can still buy lots of it," says Terry Wallace, a geophysicist and emeritus director of Los Alamos National Laboratory in New Mexico.

But, Wallace notes, the trinitite that he and colleagues studied was a rarer variety, called red trinitite. Most trinitite has a greenish tinge. Red trinitite contains copper, remnants of the wires that stretched from the ground to the bomb. Quasicrystals tend to be found in materials that have experienced a violent impact and usually involve metals. Red trinitite fits both criteria.

But first the team had to find some. "I was asking around for months looking for red trinitite," says theoretical physicist Paul Steinhardt of Princeton University. But Steinhardt, who is known for trekking to Siberia to seek out quasicrystals, wasn't deterred (*SN: 3/2/19, p. 28*). Eventually, mineralogist Luca Bindi of the University of Florence got some from a trinitite expert, who began collaborating with the team. Once Bindi extracted the tiny grain, the researchers scattered X-rays through it, revealing that the material had a type of symmetry found only in quasicrystals.

The quasicrystal, formed of silicon, copper, calcium and iron, is "brand new to science," says mineralogist Chi Ma of Caltech. "It's a quite cool and exciting discovery."

The study shows that artifacts from the birth of the atomic age are still of scientific interest, says materials scientist Miriam Hiebert of the University of Maryland in College Park, who has analyzed materials from other pivotal moments in nuclear history (*SN: 6/22/19, p. 16*). "Historic objects and materials are not just curiosities in collectors' cabinets but can be of real scientific value," she says. ■

ATOM & COSMOS

Milky Way may have matured fast

Galaxy was mostly grown before it ate its small neighbor

BY LISA GROSSMAN

The Milky Way as we know it today was shaped by a collision with a dwarf galaxy about 10 billion years ago. But most of the modern galaxy was already in place even at that early date, new research shows.

Ages of stars left behind by the galactic outsider are a bit younger or on par with stars in the Milky Way's main disk, researchers report May 17 in *Nature Astronomy*.

That could mean that the Milky Way grew up faster than astronomers expected, says astrophysicist Ted Mackereth of the University of Toronto. "The Milky Way had already built up a lot of itself before this big merger happened."

The galaxy's history is one of violent conquest. Like other large spiral galaxies in the universe, the Milky Way probably built up its bulk by colliding and merging with smaller galaxies over time. Stars from the unfortunate devoured galaxies got mixed into the Milky Way like cream into coffee, making it difficult to figure out what the galaxies were like before they merged.

In 2018, astronomers realized that they could identify stars from the last major merger using detailed maps of more than a billion stars from the European Space Agency's Gaia spacecraft. Streams of stars orbit the galactic center at an angle to the main disk of stars. Those stars' motions and chemistries suggest they once belonged to a separate galaxy that plunged into the Milky Way about 10 billion years ago (*SN: 11/24/18, p. 8*).

Two groups discovered evidence of the ancient galaxy at around the same time. One called the galaxy Gaia-Enceladus; the other group called it the Sausage. The name that stuck was Gaia-Enceladus/Sausage.

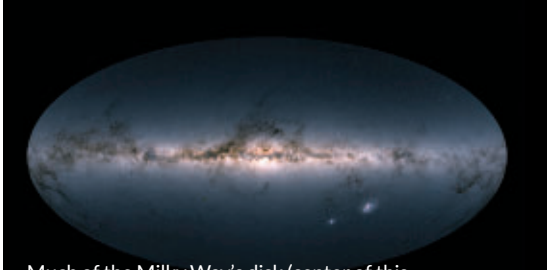
Mackereth and colleagues wondered

L. BINDI, P.J. STEINHARDT

how well developed the Milky Way was when Gaia-Enceladus/Sausage came crashing in. If the oldest stars in the Milky Way's disk formed after this merger, then they probably formed as a result of this collision, suggesting that Gaia-Enceladus/Sausage met a proto–Milky Way that still had a lot of growing up to do. On the other hand, if the oldest stars are about the same age or older than the stars from the galactic outsider, then our galaxy was probably pretty well developed at the time of the run-in.

The team used a precise tool called asteroseismology to figure out the ages of individual stars from both the Milky Way and Gaia-Enceladus/Sausage (*SN: 8/31/19, p. 11*). Just like seismologists on Earth use earthquakes to probe the interior of our planet, asteroseismologists use variations in brightness caused by starquakes and other oscillations to probe the innards of stars. From intel on the stars' interior structures, researchers can deduce the stars' ages.

The team selected 95 stars that had been observed by NASA's exoplanet-hunting Kepler space telescope. Six of those stars were from Gaia-Enceladus/Sausage, and the rest were from the Milky Way's disk. The Gaia-Enceladus/Sausage stars are slightly younger than the Milky Way stars, but all are pretty close to 10 billion years old, the team found. That suggests that a large chunk of the Milky Way's disk was already in place when Gaia-Enceladus/Sausage came crashing through. It's still possible that the incoming galaxy sparked the formation of some new stars, Mackereth says. To tell how much, scientists will need to get the ages of a lot more stars.



Much of the Milky Way's disk (center of this Gaia spacecraft image) had formed when it consumed another galaxy 10 billion years ago.

The ability to precisely age individual stars represents a step forward for galactic astronomy and would let scientists "distinguish individual events in the history of the galaxy," says astrophysicist Tomás Ruiz-Lara of the University of Groningen in the Netherlands. "In the end, that's the goal." ■

ATOM & COSMOS

Supernovas might not be gold mines

Study nixes star explosions as main source of heavy elements

BY EMILY CONOVER

A smattering of plutonium atoms embedded in Earth's crust are helping to resolve the origins of nature's heaviest elements.

Scientists had long suspected that elements such as gold, silver and plutonium are born during supernovas, when stars explode. But typical supernovas can't explain the quantity of heavy elements in our cosmic neighborhood, a new study suggests. That means other cataclysmic events must have been major contributors, physicist Anton Wallner and colleagues report in the May 14 *Science*.

The finding bolsters a recent change of heart among astrophysicists. Rather than forming in standard supernovas, many heavy elements may have formed in collisions of pairs of dense, dead stars called neutron stars, or in certain rare types of supernovas (*SN: 6/8/19, p. 10*).

Heavy elements can be produced via a series of reactions in which atomic nuclei swell larger and larger as they rapidly gobble up neutrons. This series of reactions is known as the r-process, where "r" stands for rapid. But "we do not know for sure where the site for the r-process is," says Wallner, of Australian National University in Canberra. It's like having the invite list for a gathering, but not its location, so you know who's there without knowing where the party's at.

Scientists thought they had the answer when they caught a neutron star collision producing heavy elements in 2017 (*SN: 11/11/17, p. 6*). But heavy elements show up in very old stars, which formed too early for neutron stars to have had time to collide. "There has to be something else," says theoretical astrophysicist Almudena Arcones of the Technical University of Darmstadt in Germany.

If an r-process event had recently happened nearby, some of the elements created could have landed on Earth, leaving fingerprints in the crust. Wallner and colleagues searched a 410-gram sample of Pacific Ocean crust for a type of plutonium called plutonium-244 produced by the r-process. Since heavy elements tend to be produced together in particular proportions in the r-process, plutonium-244 can serve as a proxy for other heavy elements. The team found about 180 plutonium-244 atoms, deposited within the last 9 million years.

Researchers compared the plutonium count with atoms that had a known source. Iron-60 is released by supernovas, but it is not formed by the r-process. In a small piece of the sample, the team detected about 415 atoms of iron-60.

Plutonium-244 is radioactive, decaying with a half-life of 80.6 million years. Iron-60 has an even shorter half-life of 2.6 million years. So the elements could not have been present when the Earth formed 4.5 billion years ago. That suggests their source is a relatively recent event. When the iron-60 atoms were counted up according to their depth in the crust — an indicator of how long ago they'd been deposited — the team saw two peaks at about 2.5 million years ago and at about 6.5 million years ago, suggesting two or more supernovas had occurred in the recent past.

The scientists can't say if the plutonium they detected also came from those supernovas. But if it did, the amount produced would be too small to explain the abundance of heavy elements in our cosmic vicinity, the team calculated.

That means other sources for the r-process are still needed, says astrophysicist Anna Frebel of MIT. "Supernovae are just not cutting it." ■

LIFE & EVOLUTION

Mobs of urchins butcher sea stars

In the lab, the spiny creatures turn their predators into prey

BY JAKE BUEHLER

Sea urchins are underwater lawn mowers, their unabating appetites for kelp capable of altering whole nearshore ecosystems. But the spiny invertebrates will also sink their teeth into something a bit more challenging — and dangerous — new research suggests.

In a first, scientists discovered urchins attacking and eating sea stars in a lab. The observations flip a classic predator-prey script, marine behavioral ecologist Jeff Clements and colleagues report in the June *Ethology*. But it's still unknown if this oddity of captive urchins extends to the wild.

In 2018, the team was studying common sun stars (*Crossaster papposus*) at the Kristineberg Marine Research Station in Fiskebäckskil, Sweden. At one point, Clements wanted to separate one of the sun stars for a short while and needed aquarium space. He placed the sea star in a tank containing about 80 green sea urchins (*Strongylocentrotus droebachiensis*).

"I thought, OK, there's a bunch of sea urchins in there," recalls Clements, of Fisheries and Oceans Canada in Moncton. But since sun stars are predators of urchins, he figured the sun star would be safe.

When Clements returned the next day, he couldn't find the sun star. But there was a pile of urchins on one side of the tank, with something red barely visible underneath. Clements pried the urchins off, revealing the victim. "The sea star was absolutely decimated," he says. The urchins, which hadn't been fed in about two weeks, "had just ripped it apart."

Clements and colleagues soon realized this behavior hadn't been documented before. In two trials, the team placed a single sun star in a tank filled with unfed urchins and recorded how this predator-prey role reversal played out.

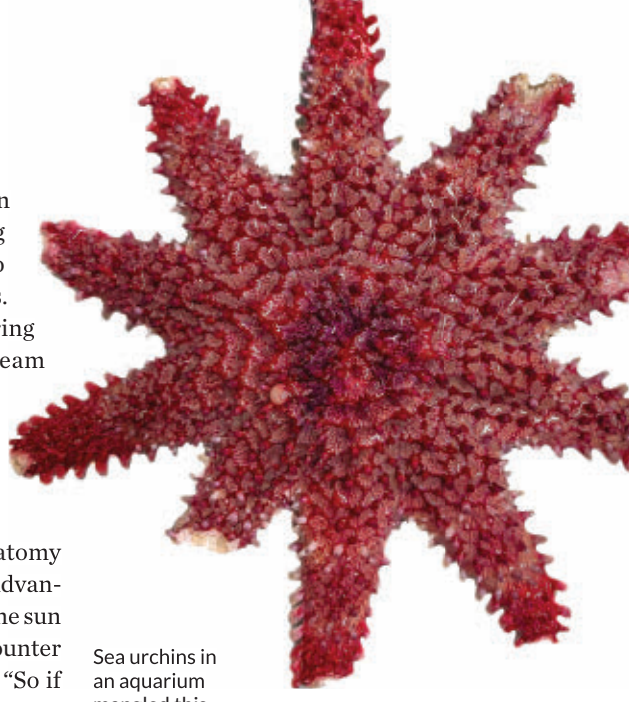
In one of the trials, one urchin approached the sun star, feeling around, eventually attaching to one of the sun star's many arms. Other urchins followed suit, covering the sun star's arms. When the team removed the urchins after about an hour, the sun star's arm tips had been chewed off, along with the sensory organs positioned there.

This aspect of the sun star's anatomy may have put the animal at a disadvantage. The tips "are the first part of the sun star that the urchin is going to encounter as it approaches," Clements says. "So if the urchin consumes those first, the sun star is going to be less effective at escaping the attacks." The team has named this incapacitating behavior urchin pinning. While urchin pinning allowed the urchins to take down one sea star, in the other trial the sea star managed to evade pinning.

It's possible the urchins are acting in self-defense, preemptively destroying a predator in their midst. Or perhaps the urchins' relative hunger fuels the attacks, says animal physiologist Julie Schram of the University of Alaska Southeast in Juneau. In crowded lab conditions with limited food — similar to this study — urchins can switch up their diet in surprising ways, Schram says. Some species have even been documented cannibalizing each other. "This would suggest to me that when starved, adult urchins will seek out alternate food sources," she says.

Urchins' capacity to feed on predatory sea stars had been hinted at before. Sea stars have turned up in urchin stomach contents, says marine biologist Jason Hodin of the University of Washington Friday Harbor Laboratories. But the findings were often interpreted as scavenging. "Active predation was the more interesting possibility, and it's satisfying to see that possibility confirmed, at least in the lab," Hodin says.

If these urchin attacks also happen in the wild, Clements thinks there could be some interesting ramifications for kelp forest ecosystems. When overabundant, urchins can graze kelp forests down to nothing, leaving behind urchin barrens (*SN: 4/24/21, p. 8*). If urchins can feed on whatever animals remain once the kelp is gone, it may be easier for urchins to persist in the barrens. And that could delay kelp forest recovery, Clements says.



Sea urchins in an aquarium mangled this common sun star, reversing a classic predator-prey relationship.

J. CLEMENTS

Discussions about possible ecosystem influences are premature and make way too much out of a "peculiar lab situation," says marine ecologist Megan Dethier, also of the University of Washington Friday Harbor Laboratories. Such urchin attacks haven't been documented in barrens, where food is scarce, she notes.

And the urchin attacks can't be intentional, since the animals don't have a brain or central nervous system, Dethier says. "Urchins doing a coordinated predatory attack is not biologically feasible."

The seemingly synchronized attacks may be a consequence of feeding urchins releasing chemical cues into the water, Clements says. Once the first urchin chews on a sun star, the other urchins may start recognizing the sun star as food.

In the future, Clements wants to run experiments manipulating urchin hunger and population density to see what factors influence the invertebrates' appetite for sun stars. ■

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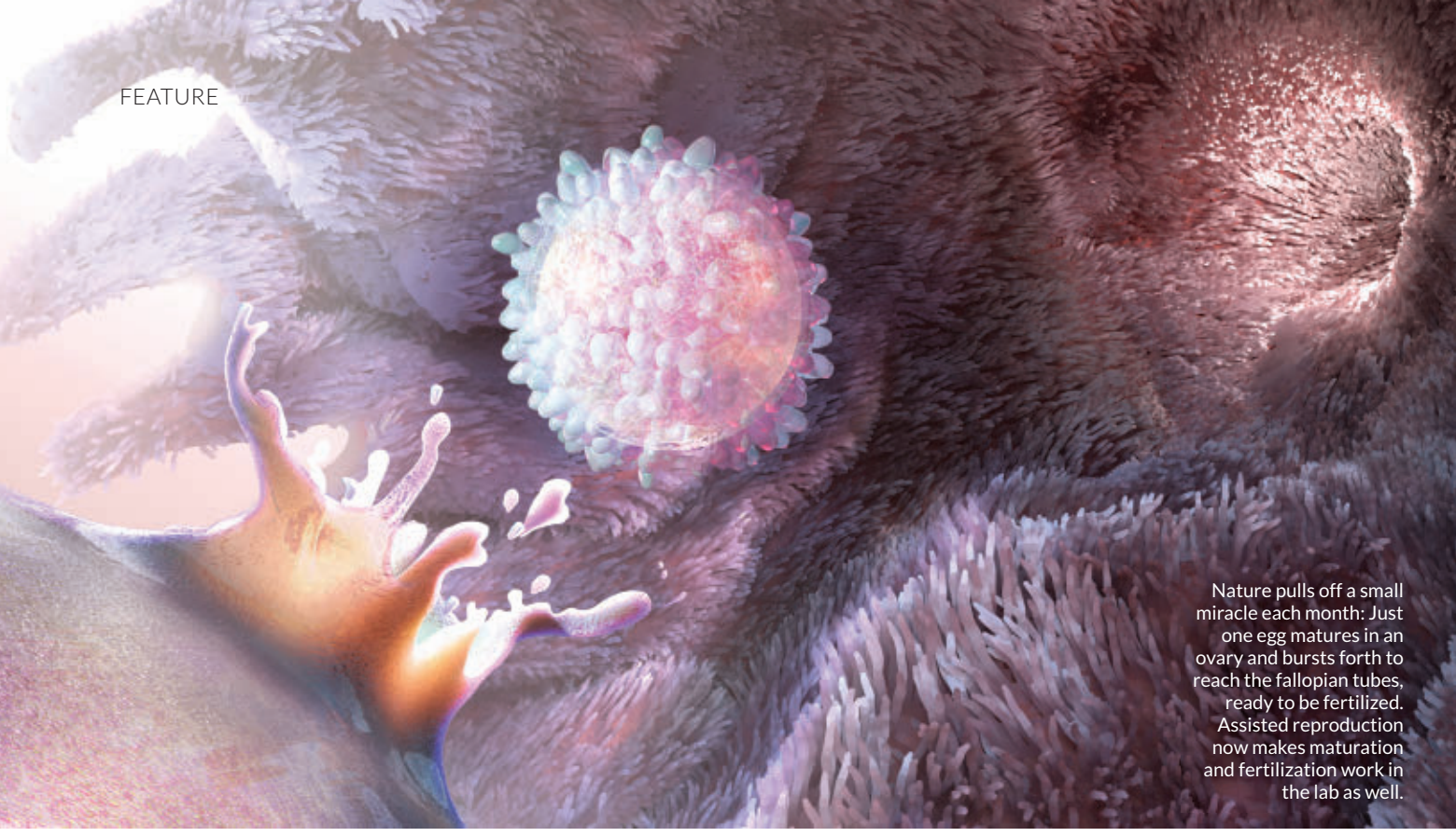


Nature pulls off a small miracle each month: Just one egg matures in an ovary and bursts forth to reach the fallopian tubes, ready to be fertilized. Assisted reproduction now makes maturation and fertilization work in the lab as well.

The Science and ART of HUMAN REPRODUCTION

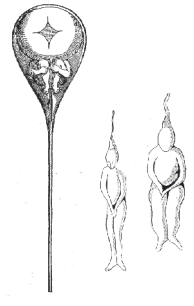
In the last 100 years, scientists have learned how to help people have babies

By Robin Marantz Henig

In the beginning, no one really understood how babies were made. Thinkers puzzled for millennia about how life arose from one generation to the next. But not until the 17th century did scientists start to seriously study the question. At that time, the theory of preformation held that minuscule humans already existed, fully formed, in either the mother's menstrual blood or the father's semen, depending on whether you were an "ovist" or a "spermist."

Little changed until two late-19th century scientists, Oskar Hertwig from Germany and Hermann Fol from France, independently conducted experiments on sea urchins, proving conclusively that creating new offspring takes one egg and one sperm.

Despite the early confusion, the ancients were sure about one thing: Reproduction is far from a sure bet. Today, an estimated 15 percent of couples worldwide are unable to conceive a child naturally, leading to feelings of sorrow, loss and a profound sense of inadequacy for many. A century ago, science didn't have much to offer these couples.



People used to think preformed humans grew inside sperm, as in this 1695 drawing.

The only fertility intervention widely available in 1921 was artificial insemination by donor sperm, which was morally and legally fraught. In the first half of the 20th century, the practice was often considered a form of adultery; as recently as 1963, an Illinois court ruled that a baby conceived this way, even with the husband's consent, was illegitimate.

In 1978, everything changed. The birth of Louise Brown, the world's first "test tube baby," proved that infertile couples had another option: in vitro fertilization. The technique involved removing a mature egg from the mother, mixing it in a lab dish with the father's sperm, and letting the fertilized egg, called a

FROM TOP: NICOLLE RAGER FULLER; NICOLAS HARTSOECKER/WIKIMEDIA COMMONS

ScienceNews 100

This article is an excerpt from a series celebrating some of the biggest advances in science over the last century. For an expanded version of the story of human reproduction, and to see the rest of the series, visit www.sciencenews.org/century

zygote, grow for a couple of days. The zygote was then returned to the mother's uterus, where it could implant and grow in an otherwise normal pregnancy.

Since Brown's historic birth, scientists have devised a range of ways to give Mother Nature a boost in baby-making. The various methods are known collectively as assisted reproductive technology, or ART. Some 9 million babies worldwide have been born using versions of ART.

The impact has been as profound sociologically as it has been medically. Now that ART has become almost routine, many of the early complaints about scientists playing God and manipulating life have faded away. Parenthood is now possible for people who never imagined it in their futures, including same-sex couples and single parents, thanks to such refinements as egg donors, surrogacy and the successful freezing of eggs, sperm and embryos. And all of it begins, as human life itself does, with the egg.

Good eggs

Even scientists can't make babies without eggs. Normally, a woman produces only one mature egg every month, and the quality of her eggs tends to decline as she reaches her late 30s. So researchers' ability to retrieve and prepare this scarce resource for fertilization, and if necessary preserve the eggs through freezing, have all been crucial in assisting reproduction.

Women have two ovaries, each one containing thousands of immature egg follicles. During the childbearing years, the ovaries usually release mature eggs in rotation: a single mature egg bursting from the right-hand ovary one menstrual cycle, from the left-hand ovary the next.

But women using ART often rely on injections of various fertility hormones to get the process going. These shots will enable sluggish ovaries to produce eggs that can be fertilized either through intercourse or in the lab via IVF. For IVF, the most robust-looking candidates are chosen to implant or to freeze for later use. This first step in ART, it turns out, is also one of the trickiest: choosing the right hormones to get the eggs you need.

Knowledge about hormones and how they affect ovulation dates back to 1923, when scientists Edgar Allen and Edward Doisy of Washington University School of Medicine in St. Louis first isolated estrogen in experimental mice and rats and found that it was produced in the ovaries. By the 1940s, scientists had elucidated the ebbs and flows of other hormones in lab animals and humans — follicle stimulating hormone, luteinizing hormone and human chorionic gonadotropin — over the course of a typical menstrual cycle.

ART usually begins with a woman giving herself daily injections containing a cocktail of these hormones, generally for 10 to 14 days. But for some women who want to have children but are dealing with a cancer diagnosis, hormone injections aren't an option — and the clock is ticking. They need to start cancer treatments as soon as possible, but many of the treatments are likely to damage the reproductive system.

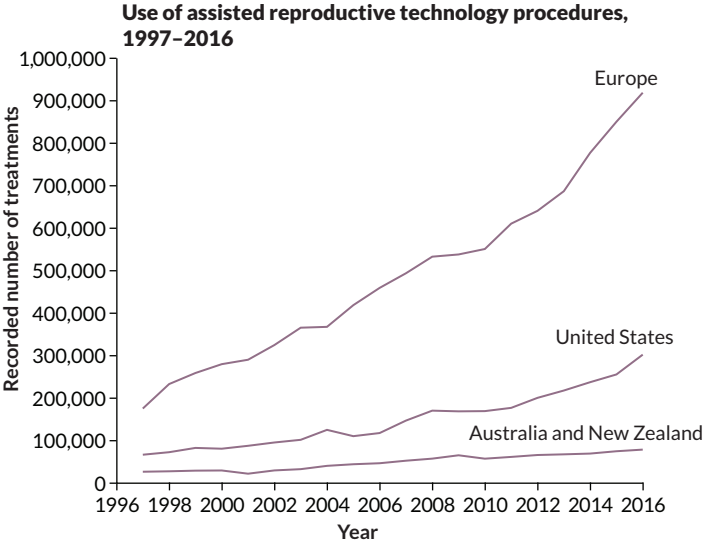
To preserve their fertility, these women might choose to freeze their eggs before cancer treatment. But they might not have 10 or so days to wait until the hormone injections provoke their ovaries to produce extra eggs — nor might they be able to take the drugs in the first place if they have a hormone-sensitive cancer, such as some breast cancers, that ovulation-stimulating drugs might make worse. So for these women, researchers had to find ways to bring a bunch of eggs to maturity all at once and outside the body — a technique known as in vitro maturation.

In vitro maturation was first used in 1934, when Harvard researchers Gregory Pincus and E.V. Enzmann used it in rabbits (*SN: 3/10/34, p. 149*). The two scientists cultured immature rabbit eggs for about a day, supplementing the nutrient broth either with extracts from cow pituitary glands or with an unspecified "maturity hormone." Both supplements helped the immature eggs grow to maturity, at which point they were successfully fertilized.

In 1940, Pincus was asked by a *New York Times* reporter what the next big development might be in reproductive science. "There are no big steps, there are all little steps," he said, declining to make any predictions. All he knew for sure, he said, was that the "big questions" of the day were: Why does an egg start to develop, and why does it continue to develop?

When reproductive endocrinologists retrieve eggs from

Helping hand Assisted reproductive technology, or ART, offers several approaches to help people have a child. ART techniques are most popular in Europe. SOURCE: C. DE GEYTER *ET AL/HUMAN REPRODUCTION* 2020



E. OTWELL

their ART patients, after either stimulating the ovaries via hormone injections or maturing the eggs in the lab, they have two choices: fertilize the eggs and implant the embryo right away, or store them. For women who are not yet ready to have a baby, storing the eggs is the best option. This is done through freezing—which, in the early days of ART, was a tricky business indeed. Eggs have a high fluid content that leads them to form crystals when frozen; during thawing, those crystals can damage the egg, especially the delicate apparatus needed to cut the cell's chromosome number in half. By dividing the chromosomes, one egg plus one sperm can fuse together without doubling the chromosome count.

In the 1980s, egg freezing worked occasionally; the first successful pregnancy using a woman's own frozen eggs, leading to the birth of healthy twins, was reported in 1986 by Christopher Chen of Flinders University of South Australia in Adelaide. But egg freezing was still a long shot. Estimates were that no more than 1 or 2 percent of thawed eggs would result in a live birth.

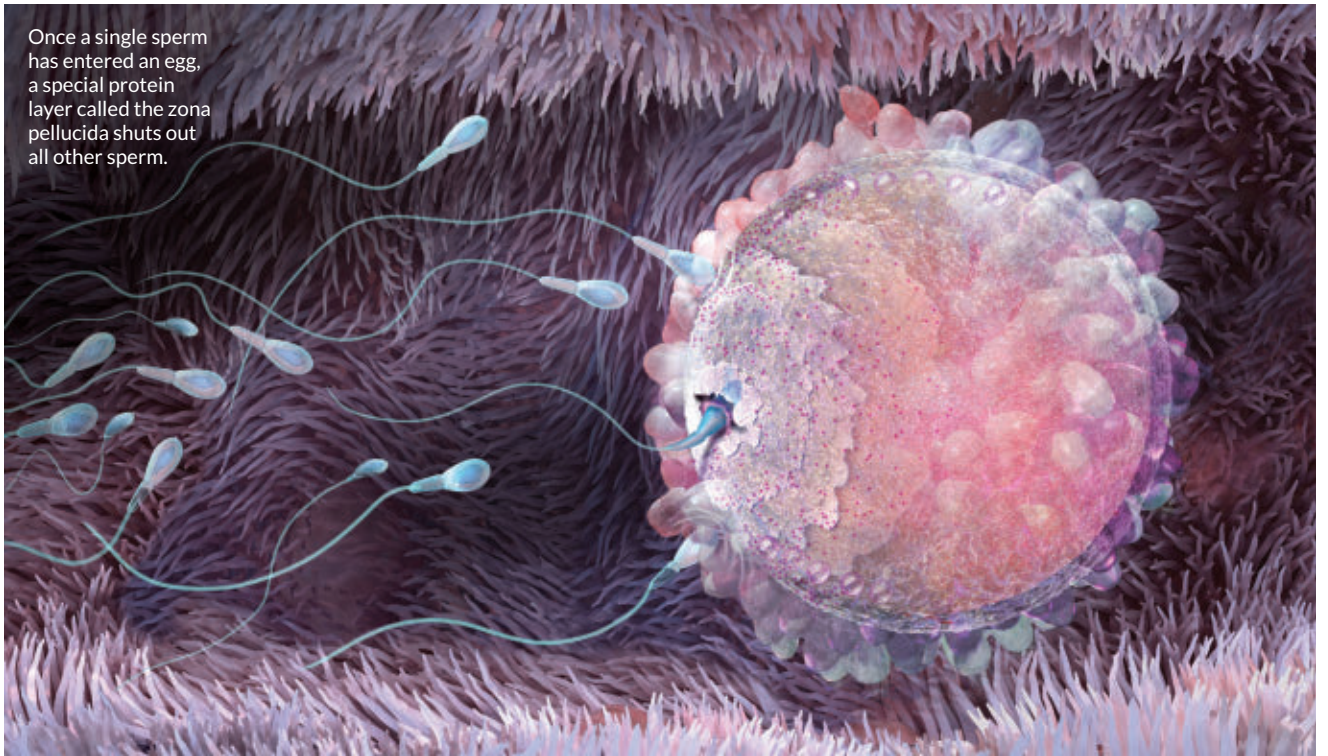
Then, in 1999, reports appeared of a more reliable freezing method: vitrification, which freezes the egg so rapidly that no ice crystals can form. A research team based in Australia and Italy described animal experiments in which 1 in 4 vitrified cow eggs were fertilized and later grew, by around day 5, to the blastocyst stage. It was only about half the rate achieved for fresh cow eggs, but it was still several times better than the rate for slow-frozen eggs. When it came to clinical use, some researchers put the live birth rate of vitrified eggs at about 2 to 12 percent for women under age 38.

At first, vitrification was limited to people who froze their eggs for medical reasons such as cancer. But in 2013, egg cryopreservation became an option for anyone who wanted to delay childbearing for any reason, medical or not.

By 2020, estimates were that a growing subset of women who choose egg vitrification each year in the United States do so because they're not ready to have children yet but hope to eventually—lifestyle-related reasons that have come to be known as "social freezing."

In the 1930s, Harvard researchers Gregory Pincus (shown) and E.V. Enzmann grew rabbit eggs to maturity and fertilized them in the lab. Pincus later went on to codevelop the birth control pill.

While social freezing is often promoted as a way to delay childbearing almost indefinitely, it turns out that most women never return to the clinic to use their frozen eggs. At McGill University in Montreal, for instance, William Buckett and his colleagues found that over the course of 13 years, the school's cancer fertility preservation program treated 353 women, of whom 9 percent died, 6 percent got pregnant spontaneously, and the majority were either still dealing with their cancer or had lost touch with the clinic for unknown reasons. Just 23 women, 6.5 percent of the group, came back to McGill to use their frozen eggs or embryos. That low return rate is also true for women who opt for social freezing.



Once a single sperm has entered an egg, a special protein layer called the zona pellucida shuts out all other sperm.

FROM TOP: BETTMANN/GETTY IMAGES; NICOLLE RAGER FULLER

Sperm meets egg

Compared with the human egg, sperm are pretty simple. They were first observed in 1677 when Antonie van Leeuwenhoek, the Dutch inventor of one of the world's first microscopes, took a look at his own ejaculate under magnification and noticed what he called "animalcules" swimming around in the sample. But their structure and function didn't come into focus until 1876, when Hertwig watched a sperm fertilize the egg of a sea urchin.

Pincus and Enzmann, who were the first to bring mammalian eggs to maturity in the lab, used rabbit sperm to achieve the first laboratory fertilization in a mammal in 1934.

It took years of struggle to make the leap from rabbits to humans. In 1951, an oddity of sperm made it seem that Pincus and Enzmann had gotten lucky. Sperm cells, it appeared, needed to be primed in some way through a process called capacitation before they could pierce the egg.

Robert Edwards of Cambridge University, one of the world's leading investigators in IVF through the 1960s and 1970s, thought capacitation would be "a terrible obstacle to IVF," recalls Roger Gosden, an embryologist who worked in Edwards' lab and authored Edwards' biography, *Let There Be Life*. He remembers some frantic attempts to mimic sperm capacitation — such as when scientists created porous chambers, roughly the size of an implanted IUD, or intrauterine device, used for contraception. The researchers would fill a chamber with sperm and insert it into the uterus of a volunteer, hoping to expose the sperm to whatever unknown capacitating substance exists in nature. After waiting a bit, the scientists would pull on a string attached to the chamber to retrieve the now "primed" sperm to see if they had indeed become better able to fertilize eggs in the lab.

In the end, scientists found an easier way. "You just have to wash the sperm to get rid of some surface constituents," Gosden says, and the sperm are ready to fertilize an egg in a lab dish. Other difficulties in clinical research proved more formidable, such as gauging the best timing of egg retrieval from women, and tweaking how many days post-fertilization were best to transfer the zygote to the uterus. Edwards and his collaborators, including gynecologist Patrick Steptoe, had more than 300 failed attempts at in vitro fertilization before their first success with Louise Brown in 1978 in England (*SN Online: 7/25/18*). Edwards went on to win the Nobel Prize in 2010 for his IVF discoveries.

Among the beneficiaries of Edwards' pathbreaking work is Claudy, who was diagnosed with breast cancer at age 29, and who in a different century might never have been able to have a baby of her own. Claudy sought out Michaël Grynberg and his colleagues at the Antoine Béclère University Hospital fertility clinic, just outside Paris, to discuss ways to preserve her fertility. It was 2014, and egg freezing through vitrification was becoming more common. But bringing an immature egg to maturity in the lab was still relatively rare. From the time of the first baby born from fresh lab-matured eggs in 1991 to the time of Claudy's arrival at Grynberg's clinic, only about 5,000 such births had occurred.

But Grynberg had no choice. He had to retrieve immature eggs from Claudy, for the sake of both speed and to avoid aggravating her hormone-sensitive breast cancer with fertility drugs. In addition, he would have to do something unprecedented in the context of cancer: Freeze those lab-matured eggs for later use. No baby had ever been born from eggs taken from a cancer patient that were matured in the lab and then frozen. (There had been one baby born at McGill in 2009 from a woman who did not have cancer, whose eggs were matured in the lab and frozen, then thawed.)

Grynberg extracted seven immature eggs and was able to grow six of them to maturity over the next 48 hours. Those six went into the deep freeze, while Claudy had surgery and chemotherapy.

A few years later, Claudy's oncologist told her it was safe to get pregnant, and she spent a year trying to conceive. But she didn't. So in 2018, she returned to Grynberg's clinic, where the doctors prepared to thaw her six frozen eggs.

To fertilize them, in Claudy's case, required an additional bit of ART. Because her eggs had been frozen, her partner's sperm would need help to fertilize her eggs. Vitrification causes changes in the egg's outer membrane that makes the thawed egg particularly hard for sperm cells to penetrate. This membrane, called the zona pellucida, is a formidable barrier even in nature (*SN: 1/3/09, p. 15*). One of the first to describe it was Sardul Singh Guraya, a biologist at Punjab Agricultural University in India, who did his early work in field rats.

The zona pellucida, Guraya reported in 1978, is a barrier around the egg made of proteins and carbohydrates, and when one sperm breaches it, cortical granules rearrange themselves to shut out all other sperm. This ensures that the zygote will have a normal genetic complement of just two pairs of 23 chromosomes, one from the mother and one from the father, rather than a grossly inflated number that would

ZUMA PRESS INC./ALAMY STOCK PHOTO

The 1978 birth of Louise Brown, a healthy baby girl, launched the field of in vitro fertilization. Although controversial at the time, IVF has been responsible for millions of births.

result if multiple sperm fertilized the egg.

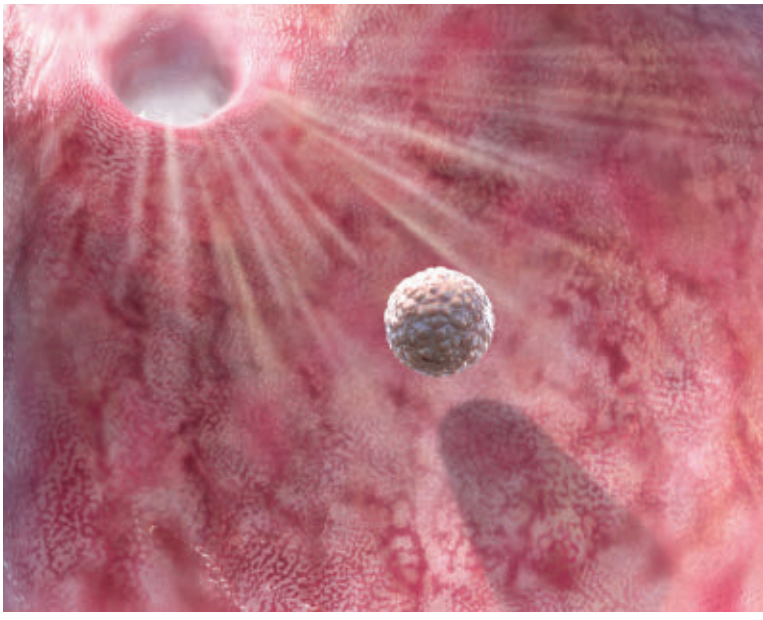
Scientists spent much of the next decade trying to get sperm into eggs that had been frozen using micro-manipulations described with such invasive terms as "zona drilling." But the sperm still failed to reach the nucleus for fertilization.

Then in 1992, Gianpiero Palermo, an Italian scientist on sabbatical from the University of Bari, reported on an accidental discovery he made while working in a fertility lab at the Free University of Brussels. When he tried to gently inject sperm beneath the outer layer of the egg, careful not to pierce the jellylike center known as the cytoplasm, he noticed that an occasional "dimple" in the membrane would allow the sperm to penetrate directly into the center anyway. When that happened, the egg was almost always fertilized. So despite the general recommendation to avoid doing so, Palermo tried injecting the sperm, tail and all, directly into the cytoplasm.

Of the first 47 attempts Palermo and his colleagues in Brussels made with this approach, 38 eggs remained intact after the injection, 31 were fertilized and 15 grew to embryos that could be transferred to a uterus.

Ultimately, four babies were born: two healthy boys from two singleton pregnancies, and a healthy pair of boy-and-girl twins. The Belgian scientists called the procedure ICSI (pronounced ICK-see), shorthand for intracytoplasmic sperm injection.

Today, injecting a single sperm directly into an egg is even more common than the traditional form of IVF that adds sperm to an egg in a lab dish to let fertilization happen on its own. The injection method is used in about two-thirds of ART cycles around the world. And it is used in virtually all cycles that, like Claudy's, start out with a hard-shelled frozen egg.



After fertilization, the blastocyst makes its way to the uterus. When an egg is fertilized in the lab, scientists can snip a cell from this developing mass to check for genetic problems without causing injury.

While a pipette (left) holds an egg in place, a single sperm is injected to fertilize the egg in a technique known as ICSI.

Growing a healthy baby

In 2018, Claudy returns to the fertility clinic at the Antoine Béclère University Hospital in suburban Paris. She is 34 years old and cancer-free. Because of the unusual nature of her case — her eggs were immature when they were retrieved and were brought to maturity in the laboratory — her doctors are not confident the eggs will survive the thawing and subsequent manipulations.

All six of Claudy's eggs defrost with no apparent damage. The scientists perform ICSI on the eggs, using fresh sperm from Claudy's partner. Five of the eggs fertilize.

These five zygotes go into an incubator so they can develop to a stage that is ready to implant. They undergo the early stages of cleavage, in which one cell becomes two, two become four, four become eight, and so on.

At many fertility clinics elsewhere in the world, doctors might interrupt things at this point to snip off a cell or two from the early embryo to see if things are progressing normally. It was revolutionary to discover that this could even be done — a feat first accomplished in 1968 by embryologist Richard Gardner. At the time, Gardner was a graduate student working in Edwards' lab in Cambridge. His work showed for the first time that it was possible in rabbits to take cells from a blastocyst without causing harm (*SN: 8/3/68, p. 119*).

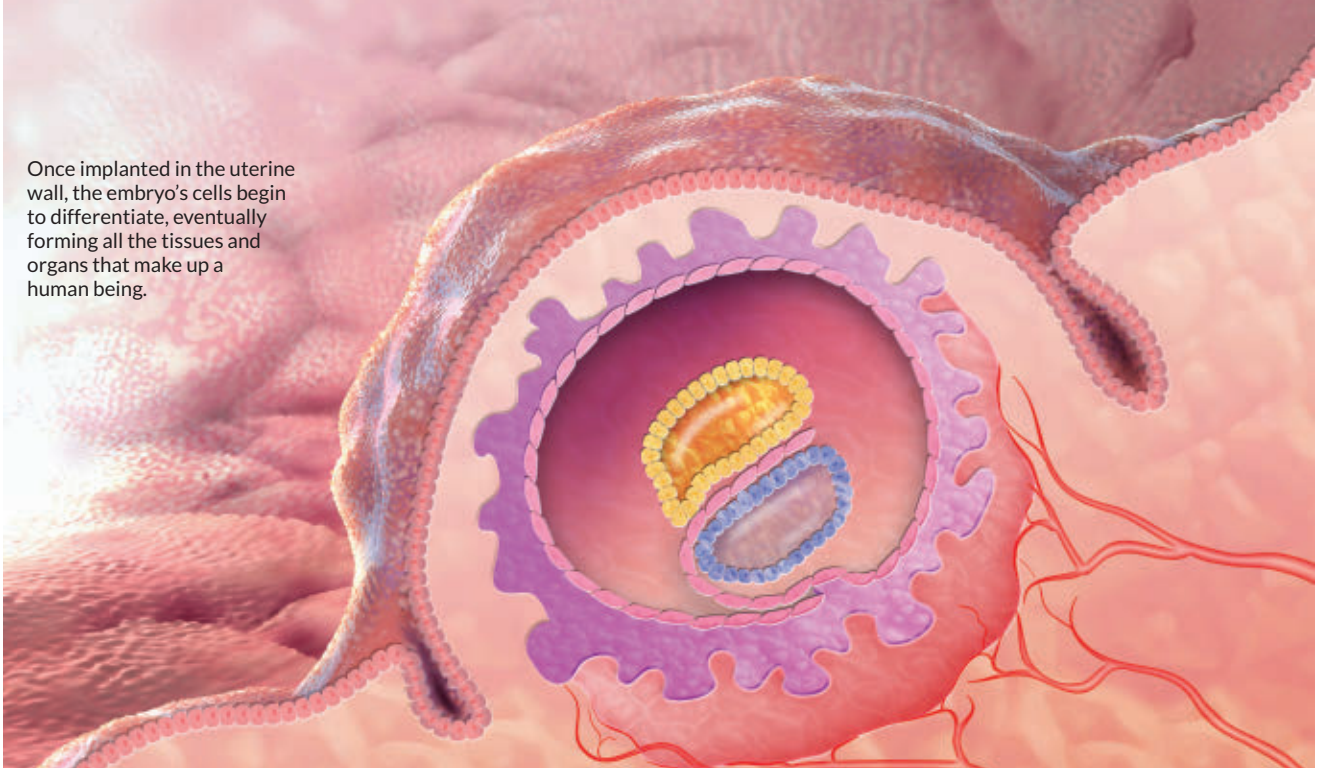
Scientists can examine the chromosomes of those cells removed from a human embryo, a process called preimplantation genetic diagnosis, or PGD. They might be looking for a particular disease-linked gene that runs in the family, to avoid implanting an affected embryo in the uterus. Or they might be checking that a developing embryo has the right number of chromosomes, and that the embryo has a good chance of implanting in the uterus and coming out a baby with 10 fingers, 10 toes and the chance of a healthy life.

In the future, they might also use PGD to see whether a desired gene tweak, introduced via a gene-editing technique like CRISPR, has actually taken hold. Without PGD, none of these approaches, from disease prevention to designer babies, could take place.

Two days after putting Claudy's five embryos in the incubator, only one is still undergoing cleavage. That is the embryo the doctors transfer to Claudy's uterus in the autumn of 2018.

The embryo implants, and continues to develop the way any embryo would, no matter what its origin story — a ball of a few hundred genetically identical embryonic cells that

FROM TOP: NICOLLE RAGER FULLER; HARDAS/SCIENCE SOURCE



Once implanted in the uterine wall, the embryo's cells begin to differentiate, eventually forming all the tissues and organs that make up a human being.

eventually differentiate into the 200 or so cell types that make up a human being. The mechanism by which this occurs was first laid out in 1924 by the German investigator Hans Spemann, who discovered the "organizer effect" that leads particular regions of the embryo to develop into particular cell types.

In 1965, Beatrice Mintz created mice that wore their bizarre genetic lineage on their unique, black-and-white striped coats. In her lab at the Institute for Cancer Research in Philadelphia, she created a mouse with four parents — two mothers and two fathers — to demonstrate which parent's genetic contribution ended up in which region of the body (*SN: 4/12/69, p. 361*).

Mintz merged eight-celled embryos from two different mice, one pure black embryo and one pure white, by putting them into a lab dish, dissolving the protective layer around each embryo, and actually smooshing them together using a glass rod. The result was a mosaic mouse: Some of its cells contained genes that could be traced directly to the two white mouse parents, and some had genes from the two black mouse parents.

Biologist Beatrice Mintz created thousands of four-parent mice, mixing different traits so she could trace the genetic origins of the distinctive organs that develop from the undifferentiated cells of a developing fetus.

FROM TOP: NICOLLE RAGER FULLER; SMITHSONIAN INSTITUTION/FLICKR

Other mysteries of how embryos develop were revealed by "knockout" technology, in which scientists disabled genes in a particular region of an embryo to see what those genes controlled. In 1995, developmental biologists William Shawlot and Richard Behringer of the University of Texas MD Anderson Cancer Center in Houston reported using this method in mouse embryos, confirming Spemann's theory that a tiny region of the embryo touches off changes in neighboring cells to turn them into particular cell types (*SN: 4/1/95, p. 197*).

The embryo in Claudy's uterus develops normally; everything about her pregnancy seems ordinary — except how miraculous it might feel to Claudy herself, who must have had some doubt, as a young breast cancer patient, about whether she'd ever have a baby of her own. In early July 2019, Claudy goes back to the Antoine Béclère University Hospital, this time to give birth. Her son is born on July 6; she and her partner name him Jules.

When Grynberg asks Claudy's permission to write up her landmark case in the *Annals of Oncology*, she is overwhelmed. "I thought about everything I had gone through," she told a reporter for the British newspaper the *Telegraph* as she posed for a photo with baby Jules. "And I cried as I realized how lucky I was." ■

Explore more

- Craig Niederberger *et al.* "Forty years of IVF." *Fertility and Sterility*. July 2018.

Robin Marantz Henig is a freelance science journalist based in New York City and author of the book Pandora's Baby: How the First Test Tube Babies Sparked the Reproductive Revolution.

For a timeline on genetic engineering in reproduction, visit **bit.ly/SN_reproductiontimeline**

TULSA RECKONS WITH THE 1921 race massacre

Archaeologists will excavate a mass grave this summer

By Helen Thompson

On May 30, 1921, Dick Rowland, a 19-year-old Black shoe shiner, walked into an elevator in downtown Tulsa, Okla. What happened next is unclear, but it sparked the Tulsa race massacre, one of the worst episodes of racial violence in U.S. history, with a death toll estimated in the hundreds.

A century later, researchers are still trying to find the bodies of the victims. A new excavation has brought renewed hope that these individuals could one day be found and identified.

By some accounts, Rowland may have tripped and bumped the arm of a 17-year-old white elevator operator named Sarah Page. Others said he stepped on her foot. Some recalled hearing her scream. Others wondered if the two had been sweet on each other and had a sort of lovers' quarrel. Whatever happened, it was a dangerous time for a young Black man to be caught in a precarious situation with a young white woman.

Engineer John Wesley Williams and his wife Loula, a teacher, shown in 1915 with their son W.D., owned Greenwood's Dreamland Theater, which was destroyed in the Tulsa massacre.

TULSA HISTORICAL SOCIETY

Tulsa's population had skyrocketed to over 100,000 people. Most of the city's African American residents, about 11,000, lived in a section called Greenwood. The neighborhood's concentration of thriving entrepreneurs earned it the nickname "Black Wall Street" from Booker T. Washington in the early 1910s.

Greenwood became an oasis from racial prejudice and violence, says Alicia Odewale, a native Tulsan and archaeologist at the University of Tulsa. "You could buy land, create businesses and raise families."

But amid its prosperity, Tulsa was extremely segregated: Oklahoma passed a Jim Crow law immediately after it became a state in 1907, the Ku Klux Klan had a hand in local politics, and lynching was common. Tulsa reflected the racial tensions and violence across the United States after World War I. "There's sort of a national pandemic of racial terror that's happening, and Tulsa is unfortunately one city among a hundred," Odewale says.

The day after the elevator incident, Rowland was arrested on a dubious charge of assault. Rumors circulated that he might be lynched. That night, white mobs invaded Greenwood, setting fires, destroying property, looting shops and murdering Black residents.

Instead of protecting the neighborhood, law enforcement handed out weapons and deputized white attackers. Machine gun fire echoed through Greenwood's streets, and private planes dropped explosives and fired on those who fled.

For 24 hours, Tulsa was a war zone.

By the evening of June 1, 35 square blocks smoldered, thousands of homes and businesses lay in ruin and a still unknown number of people were dead in the streets. A Red Cross report from 1921 suggests that about 800 people were wounded and 300 people died in the massacre, though the toll recorded by Oklahoma's vital statistics bureau was just 36: 26 Black people and 10 white.

A long history of racism, denial, deflection and cover up of the massacre has left deep wounds in the city's Black communities. A century later, Tulsans still have questions: How many people died? Who were they? And where are they buried?

Answers to some of those questions now seem within reach thanks to an investigation that in October 2020 unearthed a mass grave believed to hold massacre victims. The finding brings some of those who lost their lives one step closer to being laid to rest properly. Future steps could involve DNA analysis to put names to the remains and possibly to reunite the dead with their families. But that prospect also raises concerns about privacy. Survivors and descendants have also renewed their quest for reparations from the city and state.

Since 2018, when Tulsa Mayor G.T. Bynum launched the current investigation, Greenwood descendants and community leaders have worked side by side with a multidisciplinary team of scientists and guided the process at each step. "Not only is the whole world watching, our children are watching," says Kavin Ross, a local historian and descendant of massacre survivors. "Whatever we do, whatever we come up with, they'll see how we are playing a role in history."

This month the team begins the careful process of exhuming remains from the mass grave and analyzing bones and artifacts for clues about the identity of the individuals and how they died.

A culture of silence

As the smoke cleared on June 1, 1921, Greenwood's surviving Black residents were arrested and taken to internment sites. When they were released days later, many found themselves homeless and their neighborhood unrecognizable. No one was prosecuted for crimes committed during the massacre. Months later, Sarah Page told her lawyer she didn't wish to prosecute. The district attorney dismissed the case against Dick Rowland. Page and Rowland both left town.

Over the next year, Tulsans filed $1.8 million in claims against the city; only one, a white pawn shop owner, received compensation. Some survivors left. Those who stayed rebuilt their homes and business themselves, in spite of the city's attempts to block those efforts while blaming Greenwood residents for the violence.

For a long time, the people of Tulsa, Black and white, didn't talk much about the massacre. The story was omitted from local historical accounts, and newspapers didn't write about it until decades later. Black survivors kept quiet out of fear for their safety and because it was painful to recall.

Ross' great-grandparents Mary and Isaac Evitt owned a popular Greenwood juke joint called the Zulu Lounge, where people would go to listen to music, dance and gamble. It was destroyed during the massacre, and the family's experience

Yellow markers flag some of the burials discovered at Tulsa's Oaklawn Cemetery in October 2020. Archaeologist Kary Stackelbeck (center) draws a map of the trench. She and archaeologist Leland Bement are with the Oklahoma Archaeological Survey.

The investigation's public oversight committee, including Kavin Ross (left) and Brenda Alford (far right), served as monitors during the work at Oaklawn. Also shown are Bement (white hat) and forensic anthropologist Carlos Zambrano of the Oklahoma Office of the Chief Medical Examiner (blue hat).

BOTH: CITY OF TULSA

Lay of the land The Greenwood neighborhood of 1921 was much larger than it is today. Much of it was rebuilt after the massacre, but urban renewal policies of the 1960s plus land acquisition for a highway, ballpark and a university campus reduced Greenwood's footprint to the red area above. Three possible mass grave sites are marked with stars.

was a touchy subject for his great-aunt Mildred. "She would get angry ... refuse to even converse about it," Ross says.

Tulsans have tried to find answers and search for the dead before. Rumors have persisted for a century that bodies were buried in mass graves around Tulsa, burned in the city's incinerator and disposed of in the Arkansas River or down mine shafts outside of town. But no records of mass graves had ever been found. Death records from the period are sparse and often incomplete.

In 1997, Ross' father, state Rep. Don Ross, introduced a joint resolution in the Oklahoma legislature that launched a commission to investigate the massacre. The commission set up a telephone tip line, and Clyde Eddy called in to report what he'd seen.

Growing up, Eddy often cut through Oaklawn Cemetery on his way to his aunt's house. The then 10-year-old Boy Scout was with his cousin a few days after the massacre when they spotted wooden crates the size of pianos strewn about at the edge of the cemetery. Nearby, men were digging a trench. Curious, the boys went over to investigate. They lifted the top of one crate and saw the dead bodies of three or four people stacked inside. They opened another crate and saw the same. Just as they were about to open a third crate, grave diggers chased them off. The boys lingered for a bit at the iron cemetery fence before walking on.

Returning to Oaklawn in his 80s, Eddy showed investigators where he'd seen the trench as a boy. A Scottie-shaped metal grave marker now stood nearby. A team of scientific consultants enlisted by the commission recommended excavating at Oaklawn.

But the city never broke ground.

At the time, the commission was divided on a slew of issues, including paying reparations to survivors devastated by the massacre and how to proceed respectfully with an excavation. "We got caught up in the politics of the day," says Scott Ellsworth, a Tulsa-born historian at the University of Michigan in Ann Arbor who worked on both the 1997 investigation and the new one.

Intent on doing things differently the second time around, the city set up a series of committees to run the investigation launched in 2018: one for historical accounts, one for the physical investigation and one to provide public oversight — made up of community members who call the shots at each step of the process. Ross chairs the third group. "They're the ones in the driver's seat," Odewale says.

Digging in

By the spring of 2019, historians began sifting through tips and interviews with more than 300 people. Investigators winnowed down the information from witnesses to the most promising prospects for finding mass graves: Oaklawn Cemetery just east of downtown, Newblock Park and the Canes area just west of downtown along the Arkansas River, and Rolling Oaks Memorial Gardens cemetery south of the city.

But digging didn't begin right away.

"It's not just about sticking a shovel in the ground," says Kary Stackelbeck, the state archaeologist of Oklahoma at the Oklahoma Archaeological Survey in Norman. "You need to have a better way to narrow down your target." One way to do that is using ground surveying technology that can reveal inconsistencies among natural layers of sediment.

For the surveys, the team used a gradiometer to measure subtle magnetic variations in soil; an electrical resistance meter, which sends electric currents into the ground to detect differences in soil moisture; and ground-penetrating radar, which measures how radar pulses bounce off underground objects, giving clues about their size and depth.

Using all three complementary techniques improves the chances of finding something, says Scott Hammerstedt, another Oklahoma Survey archaeologist. For example, big metal objects can interfere with the gradiometer and power lines mess with the electrical resistance meter scans.

Archaeologists walk or push the machines over the ground like a zigzagging lawnmower. Then they look for anomalies — like waves in the gray radar scans or dark spots on gradiometer scans. "All of these things really pick up contrast between the undisturbed surrounding soil and the archaeological features that we're looking for," Hammerstedt says. Then comes the digging, to learn whether that area of contrast is in fact a grave.

At Newblock Park, flagged as a site where people had seen piles of bodies in 1921, ground scans didn't turn up anything significant. Across the train tracks and downriver from Newblock, the Canes was another area of interest.

A retired Tulsa police officer recalled seeing a photograph of bodies piled in a trench, which he found in the 1970s among boxes of images confiscated from photo studios after the massacre. He recognized the area as the Canes. That concurred

C. CHANG

White mobs began setting fire to Greenwood homes in the early hours of June 1. At sunrise, columns of smoke rose above the city. Detroit Avenue (shown) was home to prominent Black community members.

with eyewitness accounts of bodies stacked on a river sandbar and buried somewhere in the vicinity. Today, that area hosts an encampment of people who are homeless. Ground-penetrating radar flagged two areas there, each about 2 by 3 meters.

The owners of Rolling Oaks did not grant access to investigators until recently, so it was not in the initial survey.

Finally, the team surveyed Oaklawn Cemetery — where Eddy had seen those piano-sized crates a century ago. Jackson Funeral Home in Greenwood, which served the Black community at the time, had been burned to the ground. But owner Samuel Jackson was released from internment and taken to one of the city's white funeral homes to care for Black massacre victims whose bodies were being held there. The 1997 investigation had revealed death certificates of those individuals: Eighteen Black men and an infant were buried in unmarked graves somewhere at Oaklawn. In 1921, the *Tulsa Daily World* had also reported burials of Black victims at the cemetery. There lie Eddie Lockard and Reuben Everett, the only massacre victims whose graves were marked — likely because they were buried after their families were released from internment sites.

Oaklawn had three survey sites that were possible graves: an area flagged by cemetery caretakers as a place where victims were buried, a spot that matched Eddy's description in the white section of the potter's field — a burial ground for people who were poor — and an area in the Black potter's field near the two marked graves.

Scanning had shown a big, 8-by-10-meter area beneath the surface with distinct walls in the section pointed out by the cemetery caretakers. "It really had these hallmarks that suggested it might be a mass grave," Stackelbeck says.

Breaking ground

In July 2020, after a slight delay due to the COVID-19 pandemic, the team began test excavations at Oaklawn. A backhoe removed soil layer by layer, inches at a time, as archaeologists watched carefully for subtle changes in soil color and texture, and for any hint of a burial.

Gravedigging involves removing soil to the depth of several feet, then refilling the grave shaft with that soil. "Long before humans were walking around Tulsa, weathering of sedimentary rock exposed to the elements created layers of soil, and when humans come along and dig things up, those layers mix, destroying the original soil characteristics," says Deb Green, a geoarchaeologist with the Oklahoma Survey. At Oaklawn, deep soil is yellowish brown, with a crumbly texture like silt. When mixed with gray topsoil, it gets darker and starts to feel more like compact clay over time. These qualities appear both in regular graves and mass graves.

During an archaeological excavation, the goal is to stop the backhoe before it hits a burial, so the archaeologists look for

Widespread fires left many homes and businesses in Greenwood in ruins. The Red Cross estimated that 1,256 homes burned and 215 were looted in the massacre.

FROM TOP: TULSA HISTORICAL SOCIETY; LIBRARY OF CONGRESS

other clues that remains might be present. The soil above a coffin with a decaying body is darker and higher in organic carbon than the surrounding area, and sometimes contains pockets of air. Nails and hinges can leach iron that turns dirt red, and decaying wood can leave a coffin outline in the sediment.

As the backhoe dug deeper, wood fragments, glass, pottery shards and artifacts came to the surface. Remnants of overlapping historic roads and a pond emerged from the soil.

The team found a bone. But it turned out to be from a farm animal. Wearily the researchers concluded that the anomaly they'd seen in the scans was likely an old dumping ground for temporary burial markers, offerings and other debris.

"It was definitely deflating because we felt a deep sense of responsibility and there had been so much buildup," Stackelbeck says. "But this is how science works. You put together your best game plan, but sometimes the data don't play out that way."

The Original 18

The team then tried to locate the burials that Clyde Eddy saw, with no luck. Finally, the investigators turned their attention to the area of the Black potter's field and the two marked graves, a site they dubbed the Original 18, for those 18 Black men mentioned in the funeral home records.

Based on newspaper accounts and funeral home records, the team thought the Original 18 had been buried in individual graves, so the group focused on a soil anomaly that looked like a single grave. The backhoe returned and began to scrape away at the soil layers.

On the second day, it hit wood and bone. This time the bone was human. But it still caught the group off guard.

"The first burial didn't match what we expected to find, because [it] was a woman, and her casket wasn't plain," says Phoebe Stubblefield, a forensic anthropologist at the University of Florida in Gainesville who is on the excavation team and whose aunt lost her house in the massacre. The original 18 victims from the death certificates were all male and buried in plain caskets.

Bearing a simple metal plate that read "At Rest," the unidentified woman's coffin resembled a standard pauper burial of the time. "If your family couldn't afford a more formal burial, the city paid Oaklawn $5.04 to bury you in a lined casket with eight screws and a plate on top," Stubblefield says. Whoever she was, this woman was probably not a massacre victim, Stubblefield suspects.

But soil cores revealed that the disturbed area was bigger than a single grave shaft.

As the archaeologists followed the soil patterns and dug a trench, the outlines of fragile coffins began to emerge, along with human bone fragments, hinges and nails. The coffins are close together in two rows, possibly stacked. Samples of two coffin fragments revealed pine wood construction. At the end of the burial pit were steps dug into the earth.

"They were haunting," Stackelbeck says. "You don't need stairs to dig a grave for one person or even two or three people."

The crew had unearthed a mass grave.

"Here was proof that there was truth buried underneath Tulsa," says Ross, the local historian. "I felt justified."

In that trench, the investigators found 12 coffins in all, but hinges and decaying wood suggest there are at least three more. "Based on the sheer number of individuals, this certainly meets the definition of a mass grave," says Soren Blau, a forensic anthropologist at the Victorian Institute of Forensic Medicine in Melbourne, Australia. "This is not how we respectfully bury our dead," Blau says.

While historical and preservation context varies, mass graves usually consist of a large, unmarked burial pit, sometimes with steps if dug by shovel or ramping to facilitate digging by machine.

In early June, the excavation and exhumation of the remains began. The unidentified woman's burial gives researchers an idea of what they might find. Large bone fragments and teeth appear to be well-preserved, but smaller bones like vertebrae or thin rib bones likely didn't survive as well. Using trauma patterns and gender clues in the bones, Stubblefield, who also worked on the 1997 investigation, will assess whether the individuals in the mass grave are massacre victims. She'll be looking for bullet wounds and shotgun trauma. If there are actual bullets, her team might be able to determine their

Top: Forensic anthropologist Phoebe Stubblefield examines skeletal material from a soil sample at Oaklawn Cemetery on October 20, 2020. Bottom: A metal coffin plate from the first burial unearthed there reads "At Rest."

BOTH: CITY OF TULSA

caliber. Based on their location in the cemetery, the graves should be from the 1920s, when the only other mass casualty event would have been the 1918 flu pandemic. But there are no records of flu victims being buried in mass graves in Tulsa.

The researchers will also search the coffins for personal effects and textiles that could help reveal facets of the identity and social standing of the dead.

DNA insights and limits

Putting names to the deceased will be hard, and could take years. Because the death certificates of the Original 18 had scant details and listed most individuals as having died from gunshot wounds, no document has enough unique information to aid identification efforts. DNA would give the team its best chance at an ID, but after a century, any DNA extracted from teeth or bone may not be intact. Specialized techniques used to study ancient DNA might be needed.

If DNA is preserved, a clear set of rules will be needed to guide who has access to those sequences and what analyses can be done. "Academia loves genetic sequences," Stubblefield says. "We don't want to get the profiles and see 10 years of publications on Greenwood individuals without acknowledgement or communication with the community." Cautionary tales come to mind, like the use of cells from Henrietta Lacks, a Black woman diagnosed with cancer in the 1950s, who was not told her cells might be used for research, yet those cells led others to profit, making important vaccines against polio and HPV (*SN: 3/27/10, p. 30*). "There's a frequent issue with the misuse of Black bodies in science," Stubblefield says.

Finding relatives would require DNA from descendants. Consumer DNA testing companies, which have large databases, would give researchers a better chance of finding distant cousins, but using those comes with concerns about consent and privacy. Depending on company policies, that data can end up in public databases or accessed by law enforcement (*SN Online: 11/12/19*).

"You don't want to ask people to participate in the reconciliation or resolution of historical trauma in a way that might put them at risk in new ways," says Alondra Nelson, a sociologist at the Institute for Advanced Study in Princeton, N.J. In an ideal world, Greenwood-related DNA would be separated from a company's larger database or handled through private labs, she says.

The project's public oversight committee recently brought in a geneticist to talk about how DNA identification might inform the way forward. "It needs to be the community's decision," Stubblefield says. "We just want to make sure that privacy interests are addressed."

The three remaining known survivors of the massacre, all 100 years or older, are suing the city for reparations. DNA results might play a role in future reparations efforts. "Genetics can provide people with inferences and context that allow them to make claims about the past and make claims about what's owed to them in the present and future," Nelson says.

In July 2020, Kavin Ross placed candles on the grave of Eddie Lockard, one of just two massacre victims whose graves are marked at Oaklawn Cemetery.

MIKE SIMONS/*TULSA WORLD* VIA AP

Greenwood rising

Reckoning with what happened in 1921 means looking at the victims as people, not just death statistics, Odewale says. "We need to talk about how they lived, not just how they died."

Odewale leads an effort to understand the aftermath of the massacre. The goal of this work, which is happening at the same time as the mass graves project, is to search for signs of structural survival in Greenwood — building foundations, walls, anything that might have withstood the burning — and map how the neighborhood has changed since 1921. "We see cycles of both destruction and construction in Greenwood," she says. "It's not just a site of Black trauma but also one of resilience." Geophysical surveys have already turned up promising excavation prospects, and Odewale and her colleagues will break ground this summer.

The mass graves project is about finding lost ancestors, Odewale says, while her Greenwood project is about understanding the roots of the community. "We need both to move forward," she says.

Much more work lies ahead to excavate and identify remains and uncover modern complexities associated with Tulsa's buried past. The researchers hope to excavate more sites and revisit old ones. Tips are still coming in, this time through the city's website.

"We have been waiting a hundred years for what we've found so far," Ross says. "We hope that we don't have to wait another hundred years trying to find the truth." ■

Explore more

- Alicia Odewale and Karla Slocum. "#TulsaSyllabus: The rise, destruction, and rebuilding of Tulsa's Greenwood District." tulsasyllabus.web.unc.edu

To see more photos from 1921 Greenwood, visit **bit.ly/SN_Tulsa1921**

FILM

Fathom seeks to unravel whales' soulful songs

Fathom
PREMIERES JUNE 25
APPLE TV+

In an opening scene of the new film *Fathom*, Michelle Fournet sits at her computer in the dark, headphones on. The marine ecologist at Cornell University is listening to a humpback whale song, her fingers bobbing like a conductor's to each otherworldly croak and whine. Software converts crooning whale sounds into the visual space of craggy valleys and tall peaks, offering a glimpse at a language millions of years in the making.

Debuting June 25 on Apple TV+, *Fathom* follows two scientific teams studying the enigmatic songs of humpbacks. The film captivates, diving into the quest to unveil the inner world of these animals and their ever-changing song culture — one considered far older than our ancestors' first upright steps.

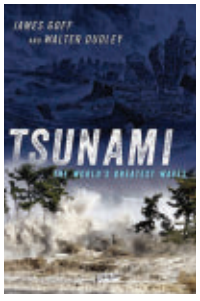
On opposite sides of the Pacific Ocean, scientists head out onto the water. In a mountain-fringed bay in Alaska, Fournet makes repeated attempts to talk to the whales, playing them a painstakingly reconstructed rendition of a yelp that she thinks may be a greeting. In French Polynesia, behavioral ecologist Ellen Garland of the University of St. Andrews in Scotland listens to humpback songs, mapping how they are tweaked, learned and shared by whales across the South Pacific. These settings are stark and gorgeous, their isolation artfully shown through silent, foggy mornings and endless cobalt seas. In a film fundamentally about oceans filled with sound, ample quiet rests on the surface.

Directed by Drew Xanthopoulos, *Fathom* portrays humpbacks and other whales as complex, highly social beings without overstated anthropomorphism. In one goose bump–inducing scene, Garland's narration identifies whales' social similarities to humans, but set in a totally different environment. Perceiving each other chiefly with sound cast over stupefying distances, "whales evolved to build relationships in the dark," Garland says.

Fathom also gives an intimate look at what scientists undertake to find humpbacks in the vast ocean. Equipment breaks. Whales prove unpredictable. Strategies must change on the fly. These moments communicate the tough realities of science and the resilience needed for successful research.

Much of the film is immersed in scenes like these, between troubleshooting and long waits on boat surveys. At times, the film's pace languishes; connections to greater perspectives, such as the possibility of a globally interlinked song culture, are touched on but not fully examined.

Nonetheless, Fournet's simple distillation of her complex quest lingers: "I'm trying to start a conversation." Her words remind us that *Fathom* is inherently seated at the threshold of unfathomable territory. — *Jake Buehler*



Tsunami
James Goff and Walter Dudley
OXFORD UNIV., $34.95

BOOKSHELF

Stories from survivors decode deadly tsunamis

On March 27, 1964, Ted Pederson was helping load oil onto a tanker in Seward, Alaska, when a magnitude 9.2 quake struck. Within seconds, the waterfront began sliding into the bay. As Pederson ran up the dock toward shore, a tsunami lifted the tanker and rafts of debris onto the dock, knocking him unconscious.

Pederson survived, but more than 100 others in Alaska did not. His story is just one of more than 400 harrowing eyewitness accounts that bring such disasters to life in *Tsunami*. Written by geologist James Goff and oceanographer Walter Dudley, the book also weaves in accounts from researchers examining the geologic record to shed light on prehistoric tsunamis.

Chapter by chapter, Goff and Dudley offer readers a primer on tsunamis: Most are caused by undersea earthquakes, but some are triggered by landslides, the sudden collapse of volcanic islands or meteorites hitting the ocean (*SN: 3/6/04, p. 152*). Readers may be surprised to learn that tsunamis need not occur on the coast: Lake Tahoe and New Zealand's Lake Tarawera are just two of many inland locales mentioned that have experienced freshwater tsunamis.

Copiously illustrated and peppered with maps, the book takes readers on a world-spanning tour of ancient and recent tsunamis, from a deep-ocean impact off the coast of South America about 2.5 million years ago to numerous tsunamis of the 21st century. The authors' somber treatment of the Indian Ocean tsunami of December 2004 stands out (*SN: 1/8/05, p. 19*). Triggered by a magnitude 9.1 earthquake, the megawave killed more than 130,000 people in Indonesia alone.

The authors — Goff is a professor at the University of New South Wales in Sydney and Dudley is a researcher at the University of Hawaii at Hilo — help readers understand tsunamis' power via descriptions of the damage they've wrought. For instance, the account of a huge wave in Alaska that scoured mature trees from steep slopes along fjords up to a height of 524 meters — about 100 meters taller than the Empire State Building — may leave readers stunned.

But it's the heart-thumping stories of survivors who ran to high ground, clambered up tall trees or clung to debris after washing out to sea that linger with the reader. They remind us of the human cost of living on the shore when great waves strike. — *Sid Perkins*

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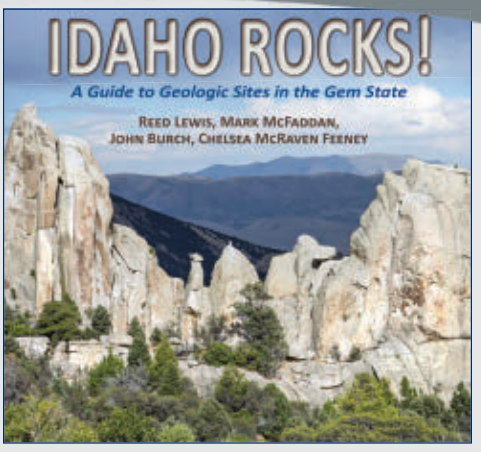

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Reed Lewis, Mark McFaddan, John Burch, Chelsea McRaven Feeney

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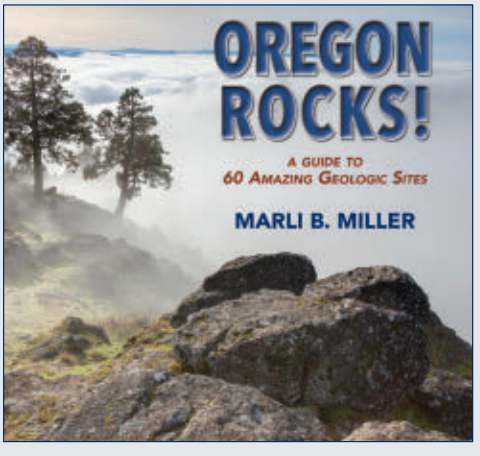

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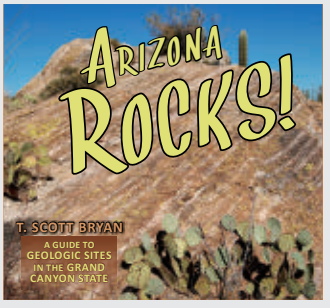

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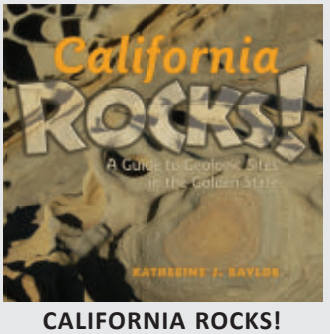

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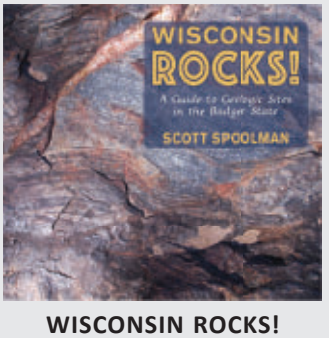

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"*Science News* is best at what it does. It's quick; it's lucid; it's intellectually rigorous."

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FROM SUBSCRIBER TO PHILANTHROPIST
Jon Graff, who started reading *Science News* in 1974, passed away on January 29, 2021. His legacy gift will ensure a prize named in his honor will be given in perpetuity.

△

FIRST GRAFF PRIZE RECIPIENTS
Anna S. Mueller (left) and Abigail L.S. Swann (right) have won the $1,000 Jon C. Graff, PhD, Prize for Excellence in Science Communication.

Legacy Gift From a Longtime *Science News* Reader

Digital cryptography pioneer Jon Graff started reading *Science News* in 1974. His love of learning about the latest advances in science, medicine and technology from *Science News* journalists continued until his death on January 29, 2021.

Jon said, "*Science News* is best at what it does. It's quick; it's lucid; it's intellectually rigorous." He also appreciated its breadth. "As much as I care about life sciences and math," he said, "I have always been fascinated by vertebrate paleontology, and I have learned about advances in all those fields in the magazine."

Jon began his career as a biochemistry and cell biology researcher, authoring 17 scientific papers. He then moved into the computer technology field as a cryptographic architect, designing secure systems for Fortune 500 companies. Jon was also awarded a patent for his work in digital communications. He is the author of *An Introduction to Modern Cryptography,* published in 2000.

In 2019, Jon provided funding to establish the Jon C. Graff, PhD, Prize for Excellence in Science Communication, an annual $1,000 award that the Society for Science gives to a scientist for their unique ability to communicate scientific ideas. The winner is selected from *Science News*' annual SN 10 list, which spotlights 10 early- and mid-career scientists who are breaking ground in their fields and are on their way to widespread acclaim.

This legacy gift contributed through Jon's estate will endow the award in perpetuity in addition to supporting *Science News* journalism.

The first two winners of the Graff Prize were Abigail L.S. Swann, associate professor of biology at the University of Washington (2019) and Anna S. Mueller, PhD, the Luther Dana Waterman associate professor of sociology at Indiana University (2020).

CLOCKWISE FROM TOP: SOCIETY FOR SCIENCE; UNIV. OF WASHINGTON; SARAH DIEFENDORF

APRIL 24, 2021

SOCIAL MEDIA

Under the sea

Octopuses snooze in brief, colorful bursts of REM-like activity, **Laura Sanders** reported in "Octopus sleep is remarkably active" (*SN: 4/24/21, p. 12*). On Facebook, reader **DeeDee Moran** wondered what the cephalopods dream about. "Their gardens in the shade!" reader **Bodisky Fain** quipped, quoting the Beatles' song "Octopus's Garden."

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Explosive snowflakes

Tiny uranium crystals in the cores of white dwarf stars could trigger nuclear reactions that blow the stars apart, ***Emily Conover*** *reported in "Uranium 'snowflakes' might spark supernovas"* (SN: 4/24/21, p. 5).

Two main types, or isotopes, of uranium on Earth are uranium-238 and uranium-235. But only uranium-235 is fissile, or can sustain a fission chain reaction, reader **Leon Maya** noted, and this isotope is less common. **Maya** wondered if the relationship between the isotopes also extends to white dwarfs.

The short answer is yes, **Conover** says. Since uranium-235 is fissile, it is the isotope that could set off explosions in white dwarfs. And because it decays more quickly than uranium-238, uranium-235 is typically less abundant, whether on Earth or in white dwarfs.

In general, scientists think that much of the uranium present in planets and stars formed from neutron star mergers (*SN: 11/11/17, p. 6*). Earth has a low concentration of uranium-235 because the merger that forged its uranium happened quite a long time ago, **Conover** says. "But a white dwarf that formed soon after a neutron star merger would have a significantly higher uranium-235 fraction than that on Earth."

Tuning in to the cosmos

A distant galaxy cluster emits an unusual radio wave pattern that is shaped like a giant jellyfish, ***Ken Croswell*** *reported in "'USS Jellyfish' is a cosmic oddball"* (SN: 4/24/21, p. 10).

Astronomers can detect the cluster at frequencies similar to those of FM radio stations, **Croswell** reported. Reader **Mike Neary** wondered why researchers consider these radio frequencies low, given that the frequencies reside in the International Telecommunication Union's "very high frequency" band, which ranges from 30 to 300 megahertz.

Radio frequencies from 30 to 300 MHz are high for Earth but low for the cosmos, **Croswell** says. Take the Low Frequency Array, or LOFAR. This radio telescope network detects cosmic frequencies between 10 and 240 MHz, the lowest frequencies observable from Earth. In contrast, the best-known frequency in radio astronomy, emitted by hydrogen atoms in space, is 1,420 MHz, a wavelength of 21 centimeters.

Video killed the radio star

Zoom and the COVID-19 pandemic helped usher in a new age of videocalling, a technology that consumers had rejected for decades, ***Anushree Dave*** *reported in "What took the videophone so long to catch on?"* (SN: 4/24/21, p. 22).

Several readers reflected on the technology's social impact and what videocalling could mean for the future.

Reader **Leah O'Connor** lauded the benefits videocalling provides for people who are deaf or have low hearing. "Zoom and some other platforms now have computer-generated captioning that is almost better than live captioning," she wrote. "Videocalling also allows for lip reading and American Sign Language.... I hope videocalling never goes away."

Though many people have relied on videocalling during the pandemic to foster a sense of togetherness and community, reader **Mike Bushroe** meditated on the negative associations with the technology that some people might develop. People may learn to connect videocalling with the trauma of the pandemic, **Bushroe** noted, including the shuttering of businesses and public venues, the isolation from loved ones, the economic impact of all the jobs lost and the risk of catching and possibly dying from the virus. Those negative associations might persist long after the pandemic, and people may have to heal from the trauma to "begin to think of Zoom meetings and get-togethers solely on their own merits," he wrote.

While many readers looked ahead to videocalling's future, **Dave's** story reminded reader **A. Michael Noll** of his past as a researcher at Bell Telephone Laboratories and AT&T. "I published much about the Picturephone and worked on video conferencing [technology] in the 1970s," **Noll** wrote. He even contributed to the videophone sequence in the 1968 film *2001: A Space Odyssey*.

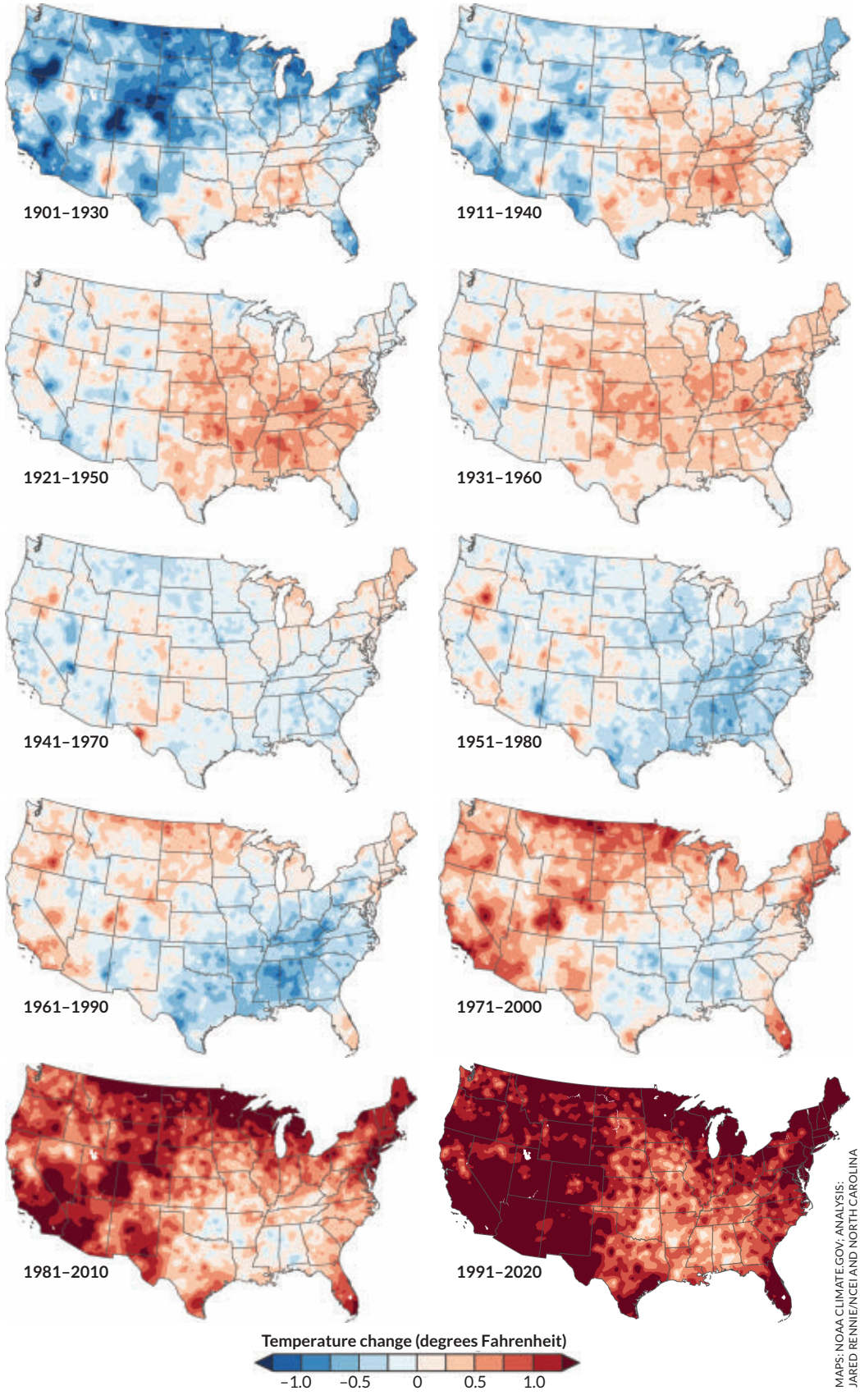
U.S. temps keep on rising

There's a new normal for U.S. weather. On May 4, the National Oceanic and Atmospheric Administration announced an official change to its reference values for temperature and precipitation. Instead of using the average values from 1981 to 2010, NOAA's new "climate normals" will be the averages from 1991 to 2020.

This new period is the warmest on record for the country. Compared with the previous 30-year span, for example, the average temperature across the contiguous United States rose from 52.8° Fahrenheit to 53.3°. Some of the largest increases were in the South as well as the Southwest, which also showed a dramatic decrease in precipitation.

The United States and other members of the World Meteorological Organization are required to update their climate normals every 10 years. These data put daily weather events in historical context and also help track changes in drought conditions, energy use and freeze risks for farmers.

That moving window of averages for the United States also tells a stark story about the accelerating pace of climate change. When each 30-year period (right) is compared with the average 1901–2000 temperature, no part of the United States is cooler now than that 20th century average. And temperatures in large swaths of the country are 1 to 2 degrees higher. — *Carolyn Gramling*



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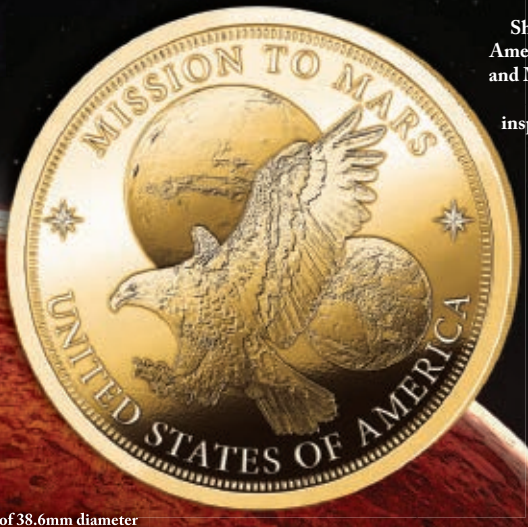

Showcases an American Eagle and Mars above the Earth, inspired by the Apollo 11 mission patch

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