Tardigrades' Speed Limit | Nuclear Clock Countdown

Science News

MAGAZINE OF THE SOCIETY FOR SCIENCE ■ JULY 3, 2021 & JULY 17, 2021

Can trees save the world?

Forests can help combat climate change, but mass planting campaigns aren't the answer

GET EDUCATION, ACHIEVE DREAMS

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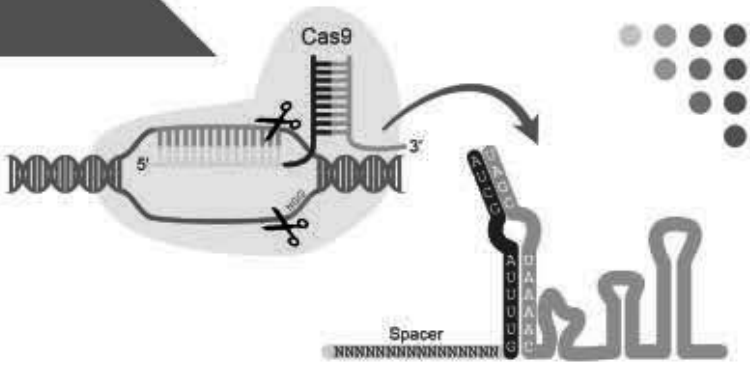

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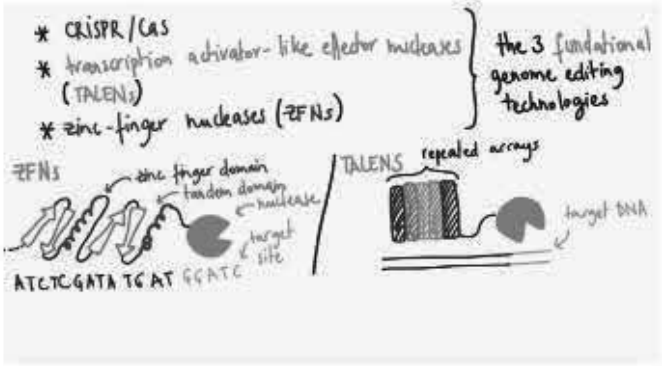

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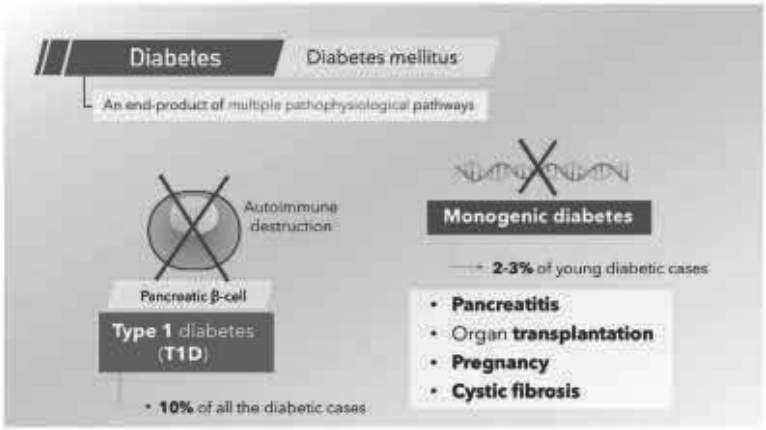

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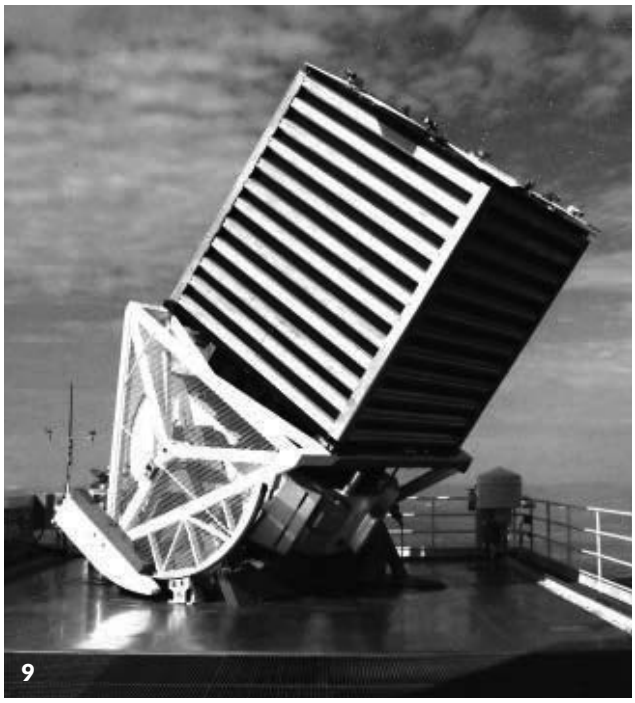
Special Report

CAN TREES SAVE THE WORLD?

News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Departments

COVER Big trees, like this karri in Western Australia, do some heavy lifting when it comes to storing carbon. © *Marie Lochman/naturepl.com*

Tasking trees with averting the climate crisis is a big ask

Trees can often appear as little more than verdant wallpaper, a fuzzy green background for humans' comings and goings. But governments and nonprofit organizations worldwide are now talking up trees as potential saviors in slowing climate change.

If only it were that simple. As our reporters explain in this special issue on trees and climate change, simply saying "add a trillion more trees!" fails to address the complexities of biology, ecosystems and human behavior.

At *Science News*, we've been thinking about trees and the roles they play on our planet for quite a while. This package of stories is the result of months of work by many writers, editors and designers identifying the big issues at stake and researching the state of the science. We wanted to find out whether this burst of enthusiasm for planting trees would end up being yet another climate quick-fix gimmick, or a lasting solution.

Earth and climate writer Carolyn Gramling dove into the question of whether trees can save us from impending climate catastrophe (Page 19). She found that many massive tree-planting efforts have failed due to lack of long-term support to keep trees alive, or because organizers failed to get buy-in from the people who live near the newly planted expanses. "It's not just a science issue," Gramling told me. "It's socioeconomic as well."

In many parts of the world, tree planting is code for tree plantations. But establishing large swaths of trees with the intention of cutting them down years later doesn't necessarily trap carbon emissions in a sustainable way. Staff writer Jonathan Lambert examined how forestry and agriculture intersect (Page 30). "It's a big topic," Lambert said. "To get my bearings I tried to talk with as many experts as I could about agroforestry." He learned that it's all about what works in a particular place and decided the best approach for the story was to zoom in on specific examples. Although he remembers the endless sameness of the fields of corn and soybeans he saw growing up in the U.S. Midwest, his interviews with people in Kenya, Costa Rica, Tanzania and upstate New York revealed how varied agricultural landscapes can look when trees become part of farms, and he learned how much extra carbon they could store.

Life sciences writer Susan Milius asked what would happen if we focused less on adding more trees, and more on appreciating the ones we already have (Page 24). Though she's been a plant partisan since childhood, she tended to appreciate vegetation more at the microscale. She remembers being startled when a hiking companion embraced a ponderosa pine tree and leaned his nose into the bark, snuffling up its rich vanilla smell. "I began to worry that I was a little tree deaf," Milius told me. Her reporting uncovered people who not only hear what trees have to say, but can enumerate essential roles of wooded areas as homes for other plants and animals, including humans. Old, big trees are best at trapping climate-altering carbon dioxide, but they also speak to many people's souls. Even spending time with the tree in your front yard can offer what Milius describes as the emotional power of communing with nature.

— Nancy Shute, Editor in Chief

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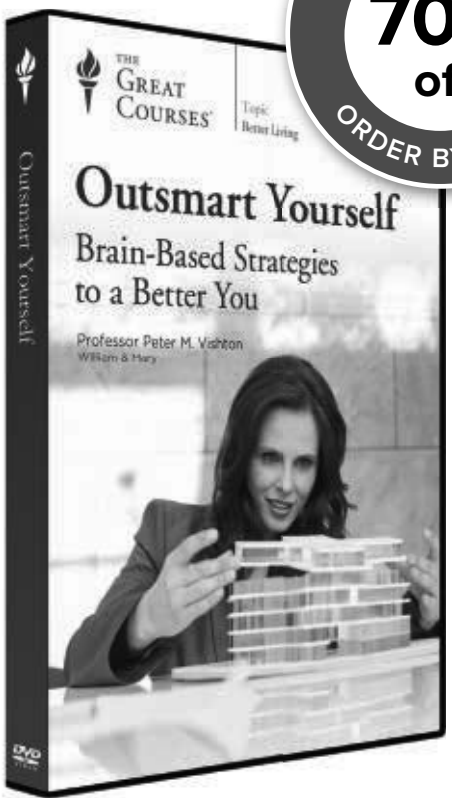

Hack Your Brain Using Neuroscience

Feeling the urge to procrastinate? Do nothing for 20 minutes and you'll feel ready to get to work. Come down with a case of the blues? Try eating some fermented foods such as yogurt or sourdough bread.

The brain is an amazing instrument, and neuroscientists today have more information than ever about how it works—as well as strategies for helping us live better every day. The surprising thing is just how counterintuitive some of these strategies can be. Unpack eye-opening insights and more in **Outsmart Yourself: Brain-Based Strategies to a Better You**. Taught by Professor Peter M. Vishton of William & Mary, these 24 practical lectures draw from a wealth of scientific evidence to take you inside your brain and show you why you behave the way you do—and what steps you can take to improve your well-being.

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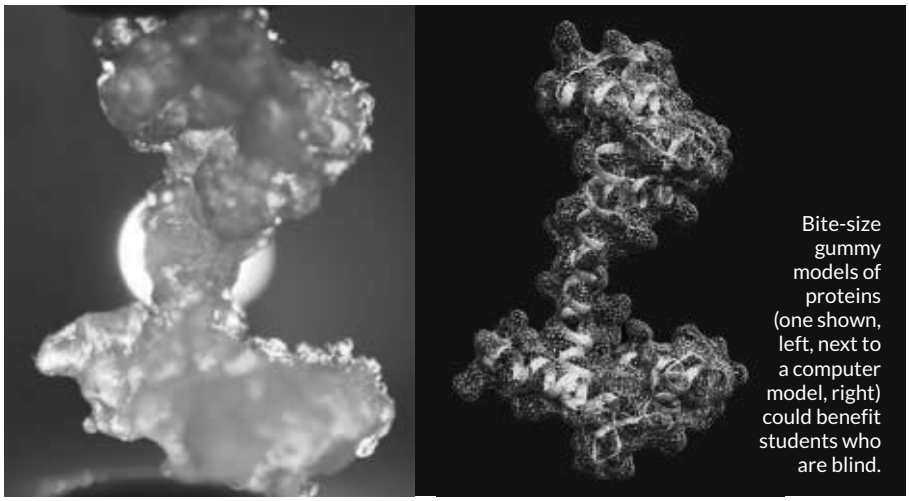
Excerpt from the July 10, 1971 issue of *Science News*

50 YEARS AGO

A virus from human cancer

[Researchers] cultured and isolated the ... virus from tissue of a child patient with Burkitt's lymphoma — cancer of the lymph nodes.... [The] work reinforces the growing body of evidence that human cancers are linked with, or caused by, a virus or viruses.... And it once again raises the possibility of a cancer vaccine.

UPDATE: Scientists estimate that a handful of viruses cause around 12 to 20 percent of human cancers. Vaccines are now available for hepatitis B virus, which can cause liver cancer, and human papillomavirus, responsible for most cervical cancers. But a vaccine for the first virus ever linked to cancer has eluded scientists. Epstein-Barr virus, or EBV, infects about 90 percent of people and can cause Burkitt's lymphoma and other cancers in a small fraction of those infected. Developing a vaccine has been a challenge partly because EBV can hide in the body for decades before causing problems. Several vaccine candidates are being tested in people, including one nanoparticle-based vaccine that may trigger a potent immune response.



Bite-size gummy models of proteins (one shown, left, next to a computer model, right) could benefit students who are blind.

THE SCIENCE LIFE

A father-son bond inspires new molecule models

Thirteen-year-old Noah Shaw loves planets and has perfect pitch. He wants to be a scientist like his father Bryan Shaw, a biochemist at Baylor University in Waco, Texas. But Noah's path to science may not be as smooth as it was for his dad.

Diagnosed with the eye cancer retinoblastoma as an infant, Noah now has only one eye and permanent blind spots in his vision. People with one eye, like Noah, and people who have blindness or limited vision, face barriers in

RETHINK

Tardigrades aren't completely bulletproof after all

Tardigrades, also known as water bears (one illustrated below), are practically unkillable. The microscopic critters can go years without food or water, withstand extreme temperatures and endure radiation and the vacuum of outer space. Now, scientists have stress-tested these death-defying creatures by firing them from a gun.

Tardigrades survived smashing into targets at speeds of up to about 825 meters per second, researchers report May 11 in *Astrobiology*. But speedier water bears blew apart on impact. The findings hint that even intrepid little animals like tardigrades would struggle to survive crash-landing on a new planet. That puts new limits on the idea that organisms might hitchhike between worlds on planetary debris.

Astrobiologist Alejandra Traspas Muiña of Queen Mary University of London and planetary scientist Mark Burchell of the University of Kent in England were inspired to test water bears' ability to withstand high-speed impacts by the tardigrade-toting Israeli spacecraft Beresheet, which crashed into the moon in 2019. "I wondered, are these tardigrades alive?" Traspas Muiña says.

The pair fired nylon bullets containing dormant *Hypsibius dujardini* tardigrades at speeds of up to about 1,000 m/s into sandbags. Given that lab collisions faster than about 825 m/s and exceeding 1 billion pascals of shock pressure proved lethal, it's unlikely the Beresheet tardigrades survived the crash, Traspas Muiña says. Likewise, space rocks usually smash into planets and moons at thousands of meters per second — too fast for tardigrades to survive. — *Maria Temming*

FROM TOP: B.F. SHAW/BAYLOR UNIV.; DOTTEDHIPPO/ISTOCK/GETTY IMAGES PLUS

STEM education. "Most of the stunning imagery in science is inaccessible to people who are blind," Bryan Shaw says. That makes him wistful, because protein renderings hooked him on science.

In an effort to help make science more inclusive, Shaw and his colleagues have come up with bite-size molecule models that are meant to be explored by the mouth's supersensitive touch sensors, which can perceive finer details than a fingertip can.

The team created both gummy candy models of proteins and 3-D printed nonedible, nontoxic versions that can be popped in the mouth for investigation. Once the researchers attached lanyards to the nonedible models to prevent choking, the team tested how well 281 college students and 31 grade-schoolers could tell models of different proteins apart while blindfolded.

Each student began with one model, examining it by mouth or by hand. For every additional protein model that the students assessed, they had to determine whether the protein was the same as the first or different. A separate group of 84 college students did the test by eyesight with 3-D computer images of proteins instead of models.

Bryan Shaw, shown with his son Noah, created protein models that can be explored by mouth.

Students correctly identified the proteins by mouth about 86 percent of the time, similar to results for groups who did the test by eye or hand, Shaw's team reports May 28 in *Science Advances*.

Such cheap, tiny models could help students learn about proteins regardless of visual acuity, Shaw says.

Shaw got the idea for this educational tool while twirling a blackberry on his tongue. A blackberry's bumpy exterior looks like a popular way that scientists depict proteins, in which each of the protein's atoms is represented by a sphere. Stick thousands of atoms together and the conglomerate resembles an elaborate berry, something the tongue might be able to tell apart by shape. He is eager for feedback on the models from students who are blind and has initiated conversations with the Texas School for the Blind and Visually Impaired in Austin.

This is not the first time that Noah has inspired his dad. Shaw codeveloped an app that can catch early signs of eye disease using childhood pictures. Whether or not Noah pursues science, his father has one wish: "I hope he does something cool." — *Carmen Drahl*

SCIENCE STATS

Vaccine equity is cost-effective

As the United States and other nations celebrate making inroads against the pandemic — with a quarter to half their populations vaccinated — many less well-off countries are lagging far behind. Some have vaccinated less than 1 percent of their populations, leaving the countries vulnerable to emerging coronavirus variants and at risk for future surges.

A new analysis puts a price tag on what it would cost for those countries to catch up. Getting COVID-19 shots to half the combined adult population of the world's lowest-income countries in 2021 would take $9.3 billion, the Rockefeller Foundation reports June 1. That estimate includes 92 nations (representing about 3.8 billion people) that are eligible for vaccine access through Gavi, the Vaccine Alliance, a public-private global health partnership based in Geneva. With that money, the alliance could buy 1.8 billion vaccine doses.

Failing to vaccinate people in countries with few resources will come with a high cost for human life — more than 3.5 million people so far have died. The world's economy stands to lose more than $9 trillion if lower-income countries can't access vaccines (*SN: 3/27/21, p. 6*). — *Betsy Ladyzhets*

$9.3 billion

Cost of immunizing half of all adults in 92 lower-income countries in 2021

Lab tests confirm ripples in Earth's magnetic field usher electrons into the atmosphere to light up auroras, like this one in Iceland.

MYSTERY SOLVED

Surfing electrons form auroras

By re-creating in the lab the conditions for an aurora, researchers have confirmed how these shimmery light shows form. Scientists have long suspected that electrons from space ride ripples in Earth's magnetic field into the upper atmosphere, where the particles collide with oxygen and nitrogen molecules to paint the sky red and green. But no satellite has observed this happening. In an experiment, physicists sent magnetic field ripples through a plasma-filled tube. Ripples swept up electrons in the plasma and accelerated the particles. The energy boost that ripples gave the electrons was similar to the boost electrons from space would need to form an aurora, the researchers report June 7 in *Nature Communications*. — *Maria Temming*

FROM TOP: COURTESY OF ELIZABETH SHAW; V2OSK/UNSPLASH

Many message-sending axons converge on a woman's brain cell (teal in this reconstruction).

BODY & BRAIN

An intricate brain map reveals quirks

3-D views of 50,000 human cells hint at neuroscience mysteries

BY LAURA SANDERS

A new view of the human brain shows its cellular residents in all their wild and weird glory. The map, drawn from a tiny piece of a woman's brain, charts the varied shapes of 50,000 cells and 130 million connections between them.

This intricate map, named H01 for "human sample 1," represents a milestone in scientists' quest to provide ever more detailed descriptions of the brain (*SN: 2/22/14, p. 22*).

"It's absolutely beautiful," says neuroscientist Clay Reid of the Allen Institute for Brain Science in Seattle. "In the best possible way, it's the beginning of something very exciting."

Scientists at Harvard University, Google and elsewhere prepared and analyzed the brain tissue sample. Smaller than a sesame seed, the bit of brain was about a millionth of an entire brain's volume. It came from the cortex — the brain's outer layer responsible for complex thought — of a 45-year-old woman undergoing surgery for epilepsy. After the brain sample was removed, it was quickly preserved and stained with heavy metals that revealed cellular structures. The sample was then sliced into more than 5,000 wafer-thin pieces and imaged with powerful electron microscopes.

Computational programs stitched the resulting images together, and artificial intelligence programs helped developmental neurobiologist Jeff Lichtman and colleagues analyze the resulting view. The team published a short description of the map May 30 at bioRxiv.org. The full dataset is freely available online.

Researchers are just beginning to see what's there. "We have really just dipped our toe into this dataset," says Lichtman, of Harvard. He compares the brain map to Google Earth: "There are gems in there to find, but no one can say they've looked at the whole thing."

Already, some "fantastically interesting" sights have appeared, he says. "When you have large datasets, suddenly these odd things, these weird things, these rare things start to stand out."

One such curiosity concerns synapses, connection spots where signals move between nerve cells. Usually, cells touch once, when a message-sending axon makes contact with a message-receiving dendrite. In the new dataset, about 90 percent of the connections were these one-hit contacts. Some pairs of cells have slightly more contacts. But every so often, researchers spotted cells that connect multiple times, including one pair that was linked by a whopping 19 synapses.

Multiple connections have been spotted in mouse brains, though not quite as abundantly as in this human sample. And fly brains can also have many connections between cells, though they're organized differently than the newly described human connections, says neuroscientist Pat Rivlin of Howard Hughes Medical Institute's Janelia Research Campus in Ashburn, Va. Rivlin works on the FlyEM Project, which aims to create detailed maps of the fruit fly nervous system.

The large dataset on the human brain provides a breakdown of just how common these types of connections are, Reid says. And that raises the question of what these extraordinarily strong synapses might be doing in the brain.

Molecular neuroscientist Seth Grant of the University of Edinburgh points out that although the map is a valuable tool, it shows only the anatomy of the brain. Other research will help clarify the function and composition of molecules that drive brain behavior. For now, the map is "very much an exploratory tool," he says.

Another curiosity to explore further is the team's observation of two nerve cells that appeared to be entwined in a symmetrical dance. The images also revealed the cells' axons forming elaborate and mysterious whorls that look like coiled snakes. "We had just never seen anything like it," Lichtman says. Once the researchers knew how to look for them, more and more coils turned up.

This extremely detailed brain map is a culmination of years of research, says Reid, who is working on maps of mouse and human brains (*SN: 8/17/19, p. 22*). "This work is just beginning to see the light of day," he says.

Whether such maps will lead to a deeper understanding of the brain is still anybody's guess. Lichtman, for one, is circumspect. "I think the best we can do is describe," he says. "I hope that at some point, we will get to a place where we are no longer surprised by what we see." ■

LICHTMAN LAB/HARVARD UNIV., CONNECTOMICS TEAM/GOOGLE

Bacteria boost counters malnutrition

Microbiome-friendly food could help undernourished children

BY JEANNE ERDMANN

In densely populated, low-income areas of Dhaka, Bangladesh, some children survive on rice cooked with curry powder and on cheap cookies and chips, packaged in appealing, colorful wrappers. These protein-poor foods provide scarce nutrients for growing bodies. Add in poor sanitation and no access to health care, and the hardship is etched in children's malnourished bodies.

"This is what life is like in these places," says Tahmeed Ahmed, who heads the International Centre for Diarrhoeal Disease Research, Bangladesh.

The situation in Dhaka is far from unique. Undernutrition is a form of malnutrition that's most common in low- and middle-income countries. According to UNICEF, 22 percent of children under age 5 globally, or 149.2 million, are coping with a form of undernutrition that leaves them short for their age. Undernutrition also leaves nearly 7 percent of young children, or 45.4 million, underweight for their height. The consequences can be deadly: Globally, 5.2 million children under age 5 died in 2019; 45 percent of those deaths were linked to nutrition-related issues, according to the World Health Organization.

ISHITA MOSTAFA

A mother in Dhaka, Bangladesh, feeds her malnourished child a supplement designed to improve health by nourishing the microbiome.

The COVID-19 pandemic was expected to make things worse, disrupting nutrition programs and families' abilities to find and afford food, researchers reported in the July 2020 *Lancet Global Health*.

It's still too early to know the toll the pandemic has had on undernutrition. "We are not yet out of the woods in many countries," says Denish Moorthy, a senior technical adviser on global nutrition initiatives for John Snow, Inc., a Boston-based public health consulting and research organization.

Yet in Dhaka, there is a glimmer of hope. Children fed a new kind of food supplement, aimed at not only nourishing them but also restoring helpful gut bacteria, gained more weight on average than children fed traditional high-calorie supplements, Ahmed and his colleagues reported in a preliminary study in the April 22 *New England Journal of Medicine*. In six months, the researchers hope to have results that determine whether those gains persist.

The approach is based on more than a decade of work led by Jeffrey Gordon, a microbiologist at Washington University School of Medicine in St. Louis, on whether disruptions in the gut microbiota can cause malnutrition. The team has found that malnourished young children lack the right proportion of beneficial gut microbes, and the problem lingers even after the children are fed foods designed to boost weight. Those gut microbes are important for metabolism, immunity, digestion and overall development, so the lack of them stymies efforts to help these kids catch up.

In Bangladesh, Ahmed, Gordon and colleagues set out to create a microbiome-repairing food supplement by testing foods common to the local diet and seeing which foods boosted beneficial bacteria. The team also characterized the gut bacteria in healthy and malnourished children and identified a pattern of markers in the blood. This pattern helped the team understand how undernutrition changes the body, and also track gut microbiome changes.

In Dhaka, the researchers gave 118 undernourished children ages 12 to 18 months either the gut microbe–friendly food or a more traditional ready-to-use supplementary food twice a day for three months. The microbe-friendly food was a mix of chickpea flour, peanut flour, soy flour, soybean oil, green banana, sugar and a vitamin-mineral mix. The standard supplement consisted of a mix of rice, lentil, sugar, soybean oil, skimmed milk powder and added vitamins and minerals.

The microbe-friendly food had fewer calories than the ready-to-use supplement — 204 Calories per 50-gram daily dose compared with 247 Calories. Still, the children on the microbe-friendly food gained weight, measured by a weight-for-length score, at about twice the rate of those given the standard supplement. Projected out to a year, this growth rate would be good enough to move these children into the normal range, Gordon says.

Blood markers linked to bone growth, nervous system development and overall health improved. A stool comparison showed that these kids' microbiomes looked like those of healthy Bangladeshi children. The results suggest that the microbe-friendly food could help turn back the clock on the ill effects of undernutrition, the researchers say.

Malnutrition has been around for a long time and efforts to combat it haven't made much of a dent, Moorthy says. "Malnutrition is not just about providing food, no matter how great the food is, or about amazing results in trials," he says. "This is the first step toward understanding some of the biology better and that is key."

Gordon's team is now working with nutrition scientists in India and with the WHO to expand the trial to other parts of the world. ■

BODY & BRAIN

FDA approves new Alzheimer's drug

But some scientists remain skeptical that aducanumab works

BY LAURA SANDERS

The U.S. Food and Drug Administration has approved a controversial Alzheimer's treatment, the first that promises to slow the disease's destruction in the brain, not just improve symptoms.

The drug, aducanumab, sold under the brand name Aduhelm, is the first new Alzheimer's treatment approved since 2003. It doesn't cure or reverse Alzheimer's disease, which affects more than 6 million people in the United States and is projected to affect nearly 13 million people by 2050.

The drug's path to approval hasn't been smooth. In 2019, aducanumab was nearly scrapped after it appeared unlikely to succeed in two large clinical trials. But after reanalyzing more data that came in later, the drug's developer, Biogen, which is based in Cambridge, Mass., saw signs that indicated the drug might work after all and decided to pursue FDA approval (*SN: 1/18/20, p. 8*).

Still, the approval concerns some doctors and scientists who see it as premature because they aren't convinced that the drug actually works. Approving a drug that's not effective would set Alzheimer's research back and offer patients false hope, those experts argue.

"This is a great day for Biogen and its shareholders, but a bleak day for the field of Alzheimer's research," says neurologist Michael Greicius of Stanford University. Pushing forward on the "illusion of progress," he says, "will come at a cost to genuine progress in finding an effective treatment for this devastating disease."

Others disagree that the evidence is slim and are elated about having a new tool to fight a disease that has long eluded an effective treatment. A drug that delays decline due to Alzheimer's promises patients time "to sustain independence, to hold onto memories longer, to be with families longer," says neuroscientist Maria Carrillo, chief science officer at the Alzheimer's Association in Chicago.

The drug, administered intravenously, is a lab-made antibody that targets small and large clumps of a sticky protein called amyloid-beta. Some researchers suspect that in Alzheimer's, A-beta scrambles connections between nerve cells and damages brain tissue, ultimately causing Alzheimer's symptoms. But that idea is still unsettled (*SN: 3/12/11, p. 24*).

Brain scans reveal that aducanumab reduces A-beta in the brain. Whether this reduction comes with consistent improvements in people's quality of life is less clear. That uncertainty led an FDA advisory panel to object to the drug's approval in November, concluding that the evidence was too weak to show that the drug effectively treated Alzheimer's.

Aducanumab comes with potentially serious side effects. About 40 percent of people who received the highest dose of the drug in a clinical trial had swelling or bleeding in the brain. While most of those participants had no symptoms, some had headaches, nausea and dizziness. ■

LYNN_BYSTROM/ISTOCK/GETTY IMAGES PLUS

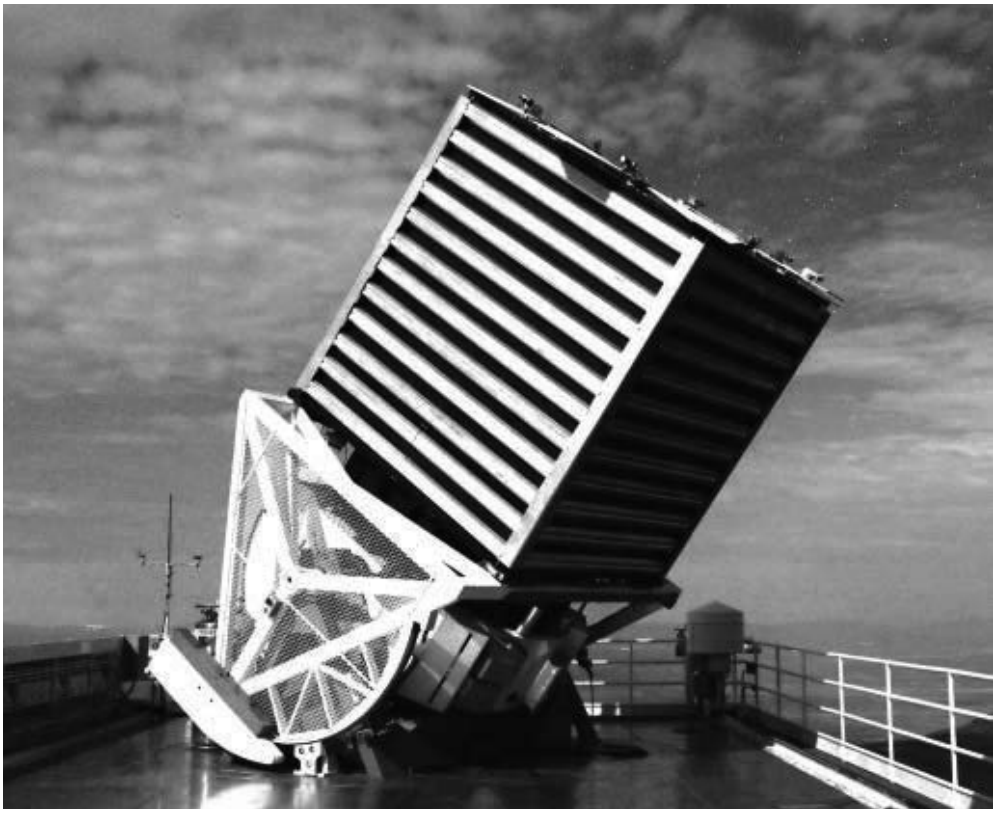
EARTH & ENVIRONMENT

Gray wolves clear deer from roadways

Gray wolves (one shown) help keep North America's deer populations in check, and by doing so, may provide an added benefit for people: curbing deer-vehicle collisions. In Wisconsin counties where wolf populations rebounded after being nearly wiped out in the mid-20th century, the number of such collisions dropped by 24 percent on average, researchers report in the June 1 *Proceedings of the National Academy of Sciences*.

Economist Jennifer Raynor and colleagues analyzed data on wolf and deer populations and deer-vehicle collisions for 63 counties from 1988 to 2010. In the 29 counties that had wolves, the predators' thinning of deer populations contributed about a 6 percent reduction in collisions over that time period. The rest of the decrease, the team proposes, was due to a "landscape of fear" — wolves' presence near roads, which the predators use as travel corridors, kept deer away. The findings suggest that hunters simply culling deer wouldn't replicate the wolves' impact, says Raynor, of Wesleyan University in Middletown, Conn.

The average drop of 38 deer-vehicle collisions per year in counties with wolves translates to about $10.9 million in annual savings across the state, the team found. Comparatively, the state paid about $3 million over the last 35 years to compensate for wolf damages. — *Jack J. Lee*



Observations of thousands of galaxies by the Sloan Digital Sky Survey telescope (left) helped reveal a purported giant arc of galaxies that is over 3 billion light-years long.

ATOM & COSMOS

Galactic arc may challenge cosmology

Newfound structure would be a 'big deal' if it actually exists

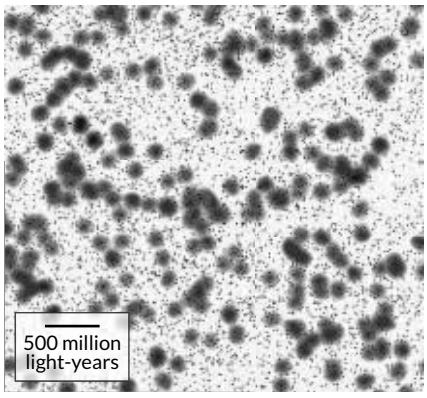
BY LISA GROSSMAN

A giant arc of galaxies appears to stretch across more than 3 billion light-years in the distant universe. If the arc turns out to be real, it would challenge a bedrock assumption of cosmology: that on large scales, matter in the universe is evenly distributed no matter where you look.

"It would overturn cosmology as we know it," cosmologist Alexia Lopez said at a June 7 news conference at the virtual American Astronomical Society meeting. "Our standard model, not to put it too heavily, kind of falls through."

Lopez, of the University of Central Lancashire in Preston, England, and colleagues discovered the purported structure, dubbed the Giant Arc, by studying the light of about 40,000 quasars captured by the Sloan Digital Sky Survey telescope in Sunspot, N.M. Quasars are the luminous cores of giant galaxies so distant that they appear as points of light. While en route to Earth, some of that light gets absorbed by atoms in and around intervening galaxies, leaving specific signatures in the light that reaches astronomers' telescopes (*SN: 7/21/18, p. 16*).

The Giant Arc's signature is formed by magnesium atoms that have lost one electron in the halos of galaxies about 9.2 billion light-years from Earth. The quasar light absorbed by those atoms traces out a nearly symmetrical curve of dozens of galaxies spanning about one-fifteenth the radius of the observable universe, Lopez reported. The structure itself is invisible on the sky to human eyes, but if you could see it, the arc would span about 20 times the width of the moon.



Astronomers claim to have found a giant arc of galaxies (smile-shaped curve, center) by mapping where on the sky light from quasars (blue specks) was absorbed by magnesium atoms in the halos (dark spots) of intervening galaxies.

"This is a very fundamental test of the hypothesis that the universe is homogeneous on large scales," says astrophysicist Subir Sarkar of the University of Oxford, who studies large-scale structures in the universe. If the Giant Arc is real, "this is a very big deal."

But Sarkar and other researchers aren't yet convinced the structure is real. "Our eye has a tendency to pick up patterns," he says, noting that some people have claimed to see cosmologist Stephen Hawking's initials written in fluctuations in the cosmic microwave background, the oldest light in the universe.

Lopez ran several statistical tests to figure out the odds that galaxies would line up in a giant arc by chance. All three suggest the structure is real, and one test surpassed physicists' gold standard that the odds of it being a statistical fluke are less than 0.00003 percent.

That sounds pretty good, but it may not be enough, Sarkar says. "Right now, I would say the evidence is tantalizing but not yet compelling," he says. More observations, from Lopez's group and others, could confirm or refute the Giant Arc.

If it is real, the Giant Arc would join a group of large-scale structures in the universe with similarly superlative names, such as the Sloan Great Wall, the Giant Gamma-Ray Burst Ring and the Huge Large Quasar Group. Taken together, this growing body of observations would break the standard model of cosmology. This model assumes that when looking at large enough swaths of space — more than about 1 billion light-years — matter is distributed evenly. The Giant Arc appears about three times as long as that theoretical threshold.

One large-scale structure "could just be a statistical fluke," Lopez said. "That's not the problem. All of them combined is what makes the problem even bigger." ■

FROM TOP: PATRICK GAULME/SLOAN DIGITAL SKY SURVEY (CC BY 4.0); A. LOPEZ

LIFE & EVOLUTION

Ancient shark die-off puzzles scientists

Over 90 percent of the predators perished 19 million years ago

BY CAROLYN GRAMLING

About 19 million years ago, something terrible happened to sharks. Fossils gleaned from Pacific Ocean sediments reveal a previously unknown shark extinction event, during which populations of the predators abruptly dropped by more than 90 percent, researchers report in the June 4 *Science*.

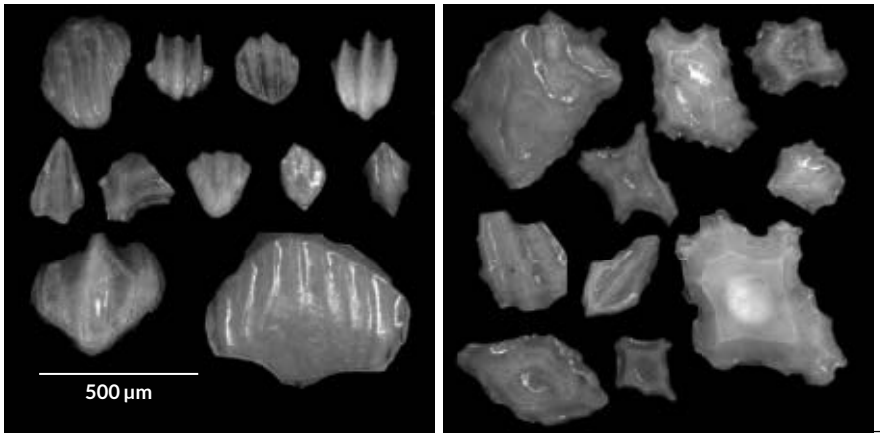
"It's a great mystery," says paleobiologist and oceanographer Elizabeth Sibert of Yale University. "Sharks have been around for 400 million years. They've been through hell and back. And yet this event wiped out 90 percent of them."

Shark diversity suffered in the aftermath of the asteroid strike that killed off all nonbird dinosaurs 66 million years ago, decreasing by 30 to 40 percent after the impact. But sharks went on to enjoy about 47 million years of peaceful ocean dominance, sailing through even large climate disruptions without much trouble (*SN: 5/30/15, p. 15*). Now, clues found in fine red clay sediments beneath the North and South Pacific add a new, surprising chapter to sharks' story.

Sibert and Leah Rubin, a marine scientist now at the State University of New York College of Environmental Science and Forestry in Syracuse, sifted through fish teeth and shark scales buried in sediment cores collected during previous research expeditions. Shark scales make for an excellent record of past shark abundance. They are readily preserved and are more plentiful than shark teeth, Sibert says.

From 66 million years ago to about 19 million years ago, the ratio of fish teeth to shark scales held steady at about 5 to 1. But abruptly — the team estimates within 100,000 years — that ratio dramatically changed, to 100 fish teeth for every 1 shark scale.

The sudden disappearance of shark scales coincided with a change in the abundances of scale shapes. That change gives some clues to changes in biodiversity. Most modern sharks have linear striations on their scales. But some sharks lack these striations and instead have scales that come in a variety of geometric



Shark scales come in two types: striated (left) and geometric (right). Geometric scales nearly vanished from ocean sediments 19 million years ago, hinting at a mass die-off of sharks.

E.C. SIBERT AND L.D. RUBIN/*SCIENCE* 2021

LIFE & EVOLUTION

Watchful canaries prepare for illness

Seeing another bird get sick may kick-start immune system

BY JONATHAN LAMBERT

For canaries, just seeing their feathered friends get sick may be enough to preemptively rev up their immune systems.

Birds housed within view of fellow fowl infected with a common pathogen mounted an immune response, despite not being infected themselves, scientists report in the June *Biology Letters*.

"It's fascinating that some sort of visual cue could alter immune function," says disease ecologist Ashley Love of the University of Connecticut in Storrs. Precisely how much the alterations protect the birds remains unclear, she says.

Immune systems patrol the body for invaders and call in the cavalry once a pathogen is detected. Usually, pathogens have to get into bodies to spur that sort of response. But previous studies have hinted that perceived threats can whip up immune cells. One experiment in humans found that looking at a photo of a sick person increased the activity of immune system chemicals called cytokines after participants' blood was exposed to bacteria. However, no one had ever looked to see whether being within eyeshot of a sick individual could compel the immune system to preemptive action, Love says.

"A lot of wildlife diseases have these obvious physical symptoms," she says. If animals can prepare immunologically at the first sign they might become infected, they may be better equipped to fight off the invader once it comes.

Love and colleagues infected 10 caged canaries with *Mycoplasma gallisepticum*, or MG, a bacterium that can cause conjunctivitis and extreme lethargy. Sick birds look "pretty fluffed out," Love says.

Nine healthy birds were housed in direct view of their sick brethren, but far enough away to avoid infection. An identical setup with all healthy birds was located in the same room but on the other side of an opaque divider. Over a month, researchers collected blood samples from the birds, measured immune activity and tracked the infected birds' appearance.

As healthy birds witnessed neighbors become visibly sick, their immune systems stirred. A measure of the birds' ability to burst foreign cells rose jointly with how sick infected birds appeared.

shapes. Before the extinction event, about a third of the scales were geometric; after, only about 3 percent were. Based on that finding, the team estimates a biodiversity loss of at least 70 percent.

There's no obvious climate event that might explain such a massive shark population shift, Sibert says. Solving the mystery of the die-off is at the top of a long list of questions she hopes to answer, which includes how the different scales might relate to shark lineages and what impact the sudden loss of so many big predators might have had on other ocean dwellers.

That last question has modern implications, Catalina Pimiento of the University of Zurich and Nicholas Pyenson of the Smithsonian National Museum of Natural History in Washington, D.C., write in a commentary in the same issue of *Science*. Shark abundances have declined by more than 70 percent over the last 50 years as a result of overfishing and climate change. "The loss of sharks from the oceans has profound, complex and irreversible ecological consequences," the paleobiologists write.

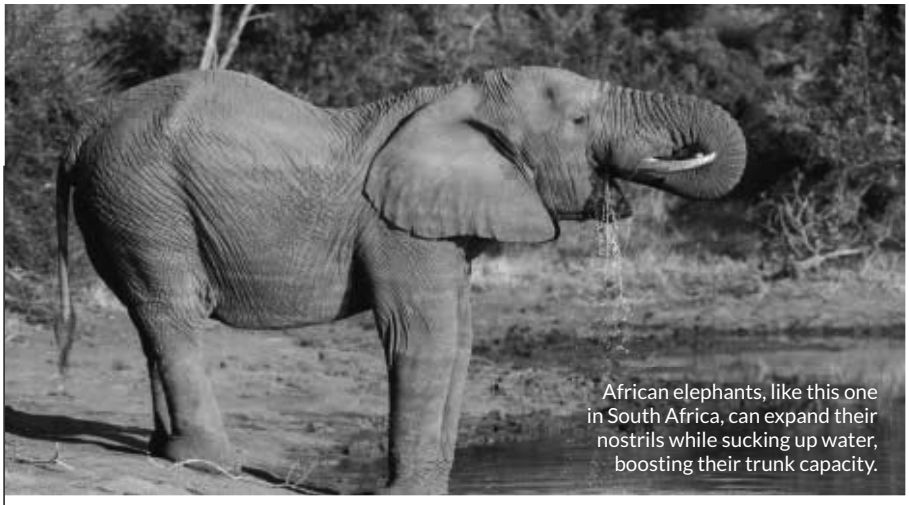
Unraveling how the ocean ecosystem responded to past losses could help researchers anticipate what may happen in the near future, Sibert says. ■

And counts of certain white blood cells were higher in birds exposed to sick individuals, rather than healthy ones. Cytokine levels did not differ between groups.

No healthy birds caught MG during the experiment, suggesting that an external cue altered immune function. That cue was likely visual, Love says. The smells and sounds of sick birds reached all birds, but only healthy birds that could see the ill birds showed an immune response.

"This was a pretty convincing study," says disease ecologist Dana Hawley of Virginia Tech in Blacksburg. For species that rely on safety in numbers, for instance, ramping up an immune response at the sight of illness might offer protection while letting the animals stay close. "It's great to avoid a pathogen," Hawley says. But if a predator catches you, "it doesn't really matter." ■

STUPORTS/ISTOCK/GETTY IMAGES PLUS



African elephants, like this one in South Africa, can expand their nostrils while sucking up water, boosting their trunk capacity.

LIFE & EVOLUTION

Elephants' snorting prowess unveiled

Ultrasound reveals what goes on inside the trunk during feeding

BY SID PERKINS

Whether or not it's possible to teach an old elephant new tricks, a 34-year-old pachyderm at Zoo Atlanta has recently taught researchers a thing or two about how elephants suck up food and water with their trunks.

For one thing, an elephant doesn't use its trunk as a simple straw. It can also dilate its nostrils to boost its trunk's carrying capacity while snorting up water, researchers report in the June *Journal of the Royal Society Interface*. That means it takes fewer snorts than expected for elephants to stock up on the water they use to drink and hose themselves down.

The surprise finding came courtesy of detailed measurements during feeding time, says mechanical engineer Andrew Schulz of Georgia Tech in Atlanta.

Elephants use a type of suction feeding that doesn't depend on lung power alone and are the only living land animals to evolve a long, boneless appendage like a trunk, Schulz says. A septum stretching the length of the trunk separates the trunk's two nostrils. But detailed knowledge of what happens inside that muscular structure during feeding has been sorely lacking.

Using ultrasound to monitor what was happening inside the trunk during feeding, Schulz and colleagues put a female African elephant through her paces during summer 2018. In some trials, the elephant snorted volumes of water that occasionally had bran mixed in.

To the researchers' surprise, each nostril's available volume ballooned by as much as 64 percent, up from the trunk's original capacity of about 5 liters. Flow rate of water through the trunk averaged about 3.7 liters per second, or the equivalent of the amount of water pouring out of 24 shower heads at once.

In other trials, the elephant was offered cubes of rutabaga. When offered just a few cubes, the elephant picked them up with the tip of her trunk. When offered piles of cubes, she switched into vacuum mode. Here, the nostrils don't expand, but rather the elephant breathes in deeply to hoover up the food.

Based on the amount and rate of water snuffed up by the elephant, the team estimated that airflow through the narrow nostrils could at times exceed 150 meters per second — more than 30 times as fast as a human sneeze, Schulz says.

The internal structure of an elephant's trunk — except for the nostrils — is similar to an octopus's tentacle or a mammalian tongue, says biomechanist William Kier of the University of North Carolina at Chapel Hill. The trunk's intricate musculature and lack of joints "create a great diversity, complexity and precision of movement," he says.

Engineers have already designed robotic devices based on an elephant's trunk, says biomechanist John Hutchinson of the Royal Veterinary College in Hatfield, England. The new findings may yield even wilder designs, he says. "You never know where bioinspiration will lead." ■

Watch a video of a feeding elephant at **bit.ly/SN_TrunkTricks**

MATTER & ENERGY

Nuclear clocks' time is coming

A better timepiece would be a win for physics and tech

BY EMILY CONOVER

Nuclear clocks could be the GOAT: greatest of all timepieces.

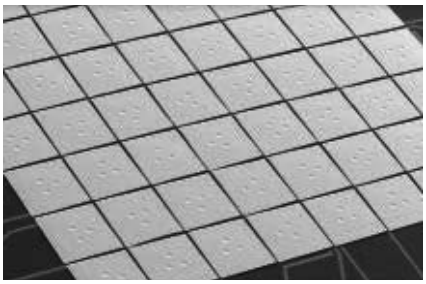
If physicists can build them, nuclear clocks would be a brand-new type of clock, one that would keep time based on the physics of atoms' hearts. Today's most precise clocks, called atomic clocks, rely on the behavior of atoms' electrons. But a clock based on atomic nuclei could reach 10 times the precision of atomic clocks, researchers estimate.

Better clocks could improve technologies such as GPS navigation, physicist Peter Thirolf said June 3 during an online meeting of the American Physical Society's Division of Atomic, Molecular and Optical Physics.

"A nuclear clock sees a different part of the world," said Thirolf, of Ludwig-Maximilians-Universität München in Germany. Unlike atoms' electrons, atomic nuclei are subject to the strong nuclear force, which holds protons and neutrons together. So nuclear clocks could allow new tests of fundamental ideas in physics, including whether supposedly immutable numbers known as fundamental constants are, in fact, constant.

Atomic clocks tally time using the energy jumps of atoms' electrons. According to quantum physics, electrons in atoms can carry only certain amounts of energy, in specific energy levels. To bump electrons in an atom from one energy level to another, an atomic clock's atoms must be hit with laser light of just the right frequency. That frequency — the rate of oscillation of the light's electromagnetic waves — serves as a highly precise timekeeper.

Like the electrons in an atom, atomic nuclei also occupy discrete energy levels. Nuclear clocks would be based on jumps between those nuclear energy levels, rather than those of electrons. Nuclei are resistant to the effects of stray electric or magnetic fields that can hinder atomic clocks. As a result, nuclear clocks "would be more stable and more accurate," says theoretical physicist Adriana Pálffy of Friedrich-Alexander-Universität Erlangen-Nürnberg in Germany.



An array of highly sensitive detectors (shown in a false-color scanning electron microscope image) allowed researchers to estimate the jump in energy of a thorium nucleus, which physicists aim to use to make a nuclear clock.

But there's a problem. To tally time with nuclei, scientists need to be able to set off the jump between nuclear energy levels with a laser. "Nuclear levels are not normally accessible with lasers," theoretical physicist Marianna Safronova of the University of Delaware in Newark said in a talk at the meeting. For most nuclei, that would require light of higher energy than suitable lasers can achieve. Luckily, there's one exception in all of the known nuclei, Safronova said, "a freak-of-nature thing." A variety of thorium called thorium-229 has a pair of energy levels close enough in energy that a laser could potentially set off the jump.

Recent measurements have more precisely pinpointed the energy of that jump, a crucial step toward building a thorium nuclear clock. Thirolf and colleagues estimated the energy by measuring electrons emitted when the nucleus jumps between the two levels, as reported in *Nature* in 2019. And in a 2020 paper in *Physical Review Letters*, physicist Andreas Fleischmann and colleagues measured other energy jumps the thorium nucleus can make, subtracting them to deduce the energy of the nuclear clock jump.

Both teams agree that the jump is just over eight electron volts in energy. That energy corresponds to ultraviolet light in a range for which setting off the jump with a laser is possible, but at the edge of scientists' capabilities.

Now that physicists know the size of the energy jump, they are aiming to trigger it with lasers. At the meeting, physicist Chuankun Zhang of the research institute JILA in Boulder, Colo., reported efforts to use a frequency comb (*SN: 10/27/18, p. 14*) — a method of creating an array of discrete frequencies of laser light — to initiate the jump and measure its energy even better. "If it's a success, we can directly build a nuclear-based optical clock from that," Zhang said. Thirolf's team also is working with frequency combs, aiming for a working nuclear clock within the next five years.

Meanwhile, Pálffy is looking into using what's called an "electronic bridge." Rather than using a laser to directly initiate an energy jump by the nucleus, the laser would first excite the electrons, which would then transfer energy to the nucleus, Pálffy reported at the meeting.

Nuclear clocks could let researchers devise new tests to determine if fundamental constants of nature vary over time. For example, some studies have suggested that the fine-structure constant, a number that sets the strength of electromagnetic interactions, could change (*SN: 11/12/16, p. 24*). "This nuclear clock is a perfect system to search for variation of fundamental constants," physicist Victor Flambaum of the University of New South Wales in Sydney said at the meeting.

The devices could also test a foundation of Einstein's general theory of relativity called the equivalence principle (*SN: 1/20/18, p. 9*). Or they could search for dark matter, elusive undetected particles that physicists think account for most of the universe's matter, which could tweak the ticking of the clock.

The potential of nuclear clocks is so promising that for Fleischmann, of Heidelberg University in Germany, it took just an instant to settle on tackling the quandary of how scientists could build a nuclear clock, he says. It was "from the very first second clear that this is a question that one should work on." ■

MATTHÄUS KRANTZ

In a first, a collider catches a neutrino

Feat demonstrates a new way to study the elusive particles

BY EMILY CONOVER

The Large Hadron Collider's claim to fame is its ability to unveil elusive subatomic particles. But there's one class of particle that it had never directly detected. Tiny neutrinos interact so little with matter that they sail through the LHC's massive detectors unnoticed.

Now, in a proof-of-concept experiment, evidence for neutrino interactions at the LHC, near Geneva, has been spotted, researchers with the FASER collaboration report May 13 at arXiv.org. The technique could open a window to neutrinos at energies for which the particles' interactions are poorly understood.

Physicists previously detected neutrinos from particle accelerators that smash particles into a stationary target. Looking for neutrinos at the LHC, which smashes beams of particles together, allows scientists to probe higher energies, but makes the neutrinos harder to study.

To find neutrinos, the team used a detector containing films similar to those used in photography. When a charged particle passes through a film, it leaves a track. Neutrinos, which have no electric charge, don't leave tracks. But when a neutrino interacts with matter, it produces a telltale spurt of charged particles.

The team put its detector in a region that neutrinos pass through as they shoot forward from particle collisions in the LHC's ATLAS detector. After estimating how many detections might be due to particles that can mimic neutrinos, the team found about six neutrino interactions.

The experiment, done before the LHC shut down for upgrades in 2018, was a test run for an experiment called FASERν. It is expected to detect about 10,000 neutrinos during the next period of LHC operations, from 2022 to 2024.

Researchers will measure neutrino cross sections, a measure of how likely the particles are to interact with material. That's important for performing other neutrino measurements. For example, scientists can learn about the production of energetic neutrinos in exploding stars and other cosmic sources by detecting them on Earth. But to determine how prevalent such neutrinos are, scientists need to know how likely those neutrinos are to interact with detectors.

Cross sections depend on particle energies. At the LHC, "we can study the energy range we haven't studied," says particle physicist Tomoko Ariga of Kyushu University in Fukuoka, Japan, a member of the FASER collaboration.

Finding neutrinos at the LHC isn't earth-shattering, says particle physicist Deborah Harris of York University in Toronto and Fermilab in Batavia, Ill. But the result shows that it's possible. "This idea is not totally crazy," she says. ■

BODY & BRAIN

Why HIV vaccines remain elusive

Virus's biology has stymied scientists for four decades

BY ERIN GARCIA DE JESÚS

Forty years ago, researchers described the mysterious cases of five gay men who had fallen ill with a pneumonia caused by the fungus *Pneumocystis carinii*. Two of the five men had already died.

That type of pneumonia usually affects only individuals who are severely immunocompromised, the researchers reported in the June 5, 1981 *Morbidity and Mortality Weekly Report*. Scientists would soon discover that a disease that would come to be known as AIDS was devastating the men's immune systems.

Three years later, scientists identified HIV, or human immunodeficiency virus, as the cause of AIDS. Margaret Heckler, who was the head of the U.S. Department of Health and Human Services, said in an April 1984 news conference that a vaccine against the virus would be ready to test within two years, holding out promise that protection was on its way.

We're still waiting. Meanwhile, the HIV global epidemic has led to devastating loss. The virus has infected more than 75 million people as of the end of 2019. An estimated 34.7 million people have died.

That toll would be much higher if it weren't for advances in antiviral treatments that can prevent infected people from dying from AIDS and from transmitting HIV to others (*SN: 11/23/19, p. 16*). To date, only three people have beaten an HIV infection (*SN: 9/26/20, p. 6*). For most, it lasts a lifetime.

Along with causing long-lasting infection, HIV is tricky to pin down; it has many variants and an ability to evade the immune system. Money is an issue too.

In stark contrast to the lack of success on an HIV vaccine, COVID-19 vaccines took less than a year to develop. Money for COVID-19 vaccine development "poured in, which was the right thing to do," says immunologist Susan Zolla-Pazner of the Icahn School of Medicine at Mount Sinai in New York City. But for other vaccines, federal funding typically comes in five-year installments, making it difficult to efficiently allocate money to get a vaccine off the ground. Still, that funding has allowed for advances in HIV research, and work on HIV helped with design of successful COVID-19 vaccines.

Activists march in Washington, D.C., in July 1983 to demand funds to fight AIDS. The U.S. government had been slow to respond to the epidemic in its early days because of stigma surrounding the gay community, which was the primary demographic affected by the disease.

The technology behind Johnson & Johnson's COVID-19 jab was first developed to tackle HIV because it triggers a strong immune response. The shot uses a common cold virus that has been altered so that it no longer causes disease. That cold virus delivers instructions to cells that tell them how to make the viral proteins needed to train the immune system to recognize the invader. Johnson & Johnson's COVID-19 vaccine uses a virus called adenovirus 26; the first HIV vaccine candidates used adenovirus 5.

But adenovirus 5 failed against HIV. Researchers halted a clinical trial testing one early vaccine when they found that participants who had previously been naturally infected with adenovirus 5 were more likely to become infected with HIV. Scientists speculated that was because those participants' immune response to that common cold virus produced a lot of infection-fighting T cells, the very cells that HIV attacks.

The absence of a good HIV vaccine is not for lack of trying, says Mark Feinberg, president and CEO of the International AIDS Vaccine Initiative in New York City. The research has been "by far the most sophisticated and creative."

HIV's bag of tricks

Much of the difficulty in making an HIV vaccine comes from the complex biology of the virus itself. One major challenge is the immense genetic diversity among HIV variants infecting people around the world. Much like the coronavirus, which has variants that are more transmissible or able to evade parts of the immune system than others, HIV has variants too. But "it's a completely different world for HIV," says virologist Morgane Rolland of the Walter Reed Army Institute of Research in Silver Spring, Md.

HIV makes new copies of its genetic blueprint at a dizzying rate, Rolland says, generating tens of thousands of new copies every day in a single person. Each of those new copies carries on average at least one unique mutation. Over the course of years, a person's body can carry myriad variants, though not all variants have the ability to infect other people. Good vaccines must spark an immune response capable of handling that vast diversity to provide broad protection against infection.

MARK REINSTEIN/ALAMY STOCK PHOTO

The main problem these variants pose for vaccines is that some mutations are in parts of the virus that the immune system tends to attack. Such changes can help the virus escape recognition.

HIV also deploys other tactics to hide from the immune system, such as covering parts of its surface in a dense layer of sugar molecules. Many of those covered parts are prime targets of immune system proteins called antibodies that latch onto viral particles.

The body recognizes the sugars as "self," says immunologist Barton Haynes of Duke University School of Medicine's Human Vaccine Institute. If antibodies attack sugarcoated virus particles, they're seen as turncoats and are eliminated. Without those antibodies, the body can't fight the virus as effectively.

But perhaps the biggest hurdle is the lifelong nature of an HIV infection. Many viruses disappear from the body when the immune system fights them off. HIV sticks around by inserting its genetic blueprint into the DNA of a host's T cells, establishing a hidden reservoir in these immune cells. Once HIV inhabits this hideout, the immune system can't eradicate the virus, nor can drug treatments. "You've got to have protective immunity there the day, the moment of transmission," Haynes says. Otherwise, "the virus has won."

Most vaccines don't stop infections from ever happening — a type of immunity called sterilizing immunity. Instead, shots are more likely to prevent people from becoming severely ill. That's not an option with HIV since it never leaves the body, Zolla-Pazner says. "It's a very different bar that we have to jump over."

A prime vaccine candidate

To date, only six clinical trials have been completed testing the efficacy of potential HIV vaccines in people. Of those, just one vaccine candidate reduced the risk of infection.

The successful trial, known as RV144, used a "prime-boost" strategy. Beginning in 2005, participants received four "prime" jabs containing a harmless virus that delivered to their cells the genetic instructions for making select HIV proteins. Participants then received two "boost" injections of an HIV protein fragment that is essential for the virus to enter cells. Scientists had hoped vaccinated participants would develop a strong immune response that protected against many HIV variants.

Ultimately, the strategy lowered infection risk by 31.2 percent in vaccinated participants compared with unvaccinated people, researchers reported in 2009 in the *New England Journal of Medicine*. Although the shots showed modest efficacy, the findings were not robust enough to release the vaccine for use.

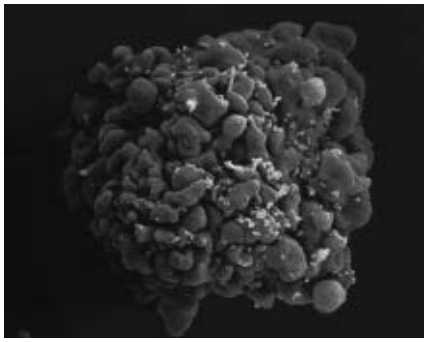
A recent follow-up trial conducted in South Africa has produced discouraging results. In February 2020, scientists stopped the trial because the prime-boost strategy didn't lower vaccinated people's HIV infection risk, the team reported in the March 25 *New England Journal of Medicine*.

Despite the setbacks, scientists used the RV144 findings to home in on the specific immune proteins people need to prevent infection, Zolla-Pazner says. If scientists could push people to make those protective HIV antibodies, then perhaps a vaccine would be within reach.

Schooling the immune system

There are now hopeful signs that vaccine developers might be on the right track to make an effective shot that provides sterilizing immunity. One approach taps into the idea that some people with HIV naturally make broadly neutralizing antibodies that can attack numerous variants and stop them from infecting cells (*SN: 8/19/17, p. 7*).

It's been an uphill battle to design a vaccine that prevents HIV (yellow granules in this false-color scanning electron micrograph of a T cell) from infecting people.



NIAID/FLICKR (CC BY 2.0)

But these antibodies develop long after an HIV infection has taken hold, Haynes says. One way to speed up the process, being tested now in a clinical trial led by Johnson & Johnson, employs an HIV protein made from variants circulating around the world to spark a strong immune response that could include broadly neutralizing antibodies.

Another method is to teach the immune system to specifically make those antibodies. Researchers are identifying such immune proteins in people with HIV and analyzing the steps the body took to create the antibodies. The goal is to craft a vaccine that tells the immune system to make similar antibodies when exposed to specific viral fragments, says vaccinologist Kevin Saunders of the Duke Human Vaccine Institute.

In 2019 in *Science*, Saunders, Haynes and colleagues reported that the immune systems of vaccinated mice and rhesus macaques spurred the first steps of making HIV antibodies that might eventually become broadly neutralizing. A separate effort by Feinberg and his colleagues showed that 97 percent of human participants in a small clinical trial made immune cells that generate broadly neutralizing antibodies when exposed to an altered piece of HIV.

Other groups are focusing on T cells. One vaccine candidate causes specialized T cells to kill HIV-infected T cells, researchers reported in the March 25 *Science Immunology*.

That team had previously shown that around half of vaccinated monkeys were protected from long-term infection. Though the animals became infected with the primate equivalent of HIV, the virus couldn't replicate well and over time the infection went away, says immunologist Louis Picker of Oregon Health & Science University in Portland. Testing the vaccine in people is the next step.

Finally, there is some light at the end of the tunnel. "I do believe we'll get a vaccine," Zolla-Pazner says. "But I don't know how long that's going to take." ■

HUMANS & SOCIETY

People reached the Americas about 30,000 years ago, new clues suggest

Humans may have inhabited what's now southern Mexico surprisingly early, between about 33,000 and 28,000 years ago, researchers report May 19 in *Latin American Antiquity*.

If so, those people arrived more than 10,000 years before folks often tagged as the first Americans (*SN: 8/4/18, p. 7*). Other preliminary evidence puts humans in central Mexico as early as around 33,000 years ago (*SN: 8/15/20, p. 6*).

The latest evidence comes from animal bones found stored in a Mexico City lab. The bones had been excavated in the 1960s at a rock-shelter called Coxcatlan Cave. Radiocarbon dating of six rabbit and hare bones from the site's deepest sediment yielded unexpectedly old ages. That sediment also contained chipped and sharp-edged stones regarded as tools by the site's lead excavator.

Higher sediment layers yielded clearer examples of stone tools and other remnants of human activity dating to nearly 9,900 years ago. Biological anthropologist and archaeologist Andrew Somerville of Iowa State University in Ames and colleagues initially suspected that animal bones from the deepest sediment were perhaps around 12,000 years old. But analyses revealed they were much older, hinting humans were living in the cave roughly 30,000 years ago.

The team will next determine whether other animal bones from the ancient sediment display butchery marks, breaks where marrow was removed or burned patches from cooking. — *Bruce Bower*

GENES & CELLS

After spending years in space, mouse sperm produce healthy pups

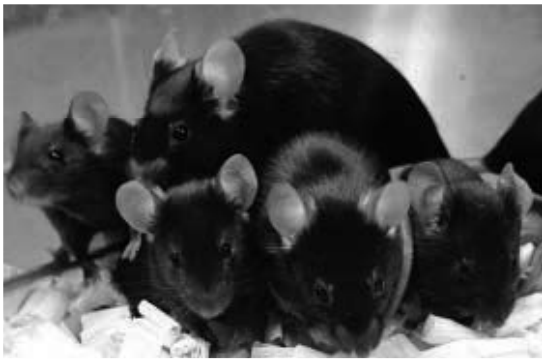
Sperm appear to be unfazed by long stints in outer space. In the longest biological experiment on the International Space Station yet, freeze-dried mouse sperm remained viable after nearly six years in space. Exposure to space radiation didn't seem to harm sperm DNA or the cells' ability to produce healthy "space pups," researchers report June 11 in *Science Advances*.

That may be good news for future spacefarers. Scientists have worried that chronic exposure to space radiation might not only put astronauts at risk for cancer and other diseases, but also create mutations in their DNA that could be passed down to future generations (*SN: 11/7/20, p. 5*). The new results hint that deep-space travelers could safely bear children.

Studying how space radiation affects reproduction is tricky. Instruments on Earth can't perfectly mimic space radiation, and the space station lacks freezers for long-term cell storage. So biologist Teruhiko Wakayama of the University of Yamanashi in Kōfu, Japan, and colleagues freeze-dried sperm, allowing for room-temperature storage. The team then sent sperm from 12 mice to the space station, while keeping other sperm from the same mice on the ground.

After the sperm cells returned to Earth, the team rehydrated them, injected them into fresh mouse eggs and transferred the embryos to female mice. About 240 healthy space pups were born from sperm kept on the space station for nearly three years; about 170 others were born from sperm kept on the space station for nearly six years. Genetic analyses revealed no differences between the space pups and mice born from sperm stored on Earth. Space pups that mated as adults had healthy children and grandchildren.

Though these results are promising, they may not capture the full effects of space radiation, since the space station is partially shielded from radiation by Earth's magnetic field. Also, space radiation can damage DNA by shattering water molecules in cells. Since freeze-dried sperm didn't contain water, it may have been especially resistant to radiation. — *Maria Temming*



After being exposed to radiation in space for up to about six years, mouse sperm produced hundreds of healthy pups (some shown).

T. WAKAYAMA/UNIV. OF YAMANASHI

ATOM & COSMOS

Physicists dream big with an idea for a particle collider on the moon

If you could peer into a particle physicist's daydream, you might spy a vision of a giant lunar particle accelerator. Now, researchers have calculated what such an enormous machine could achieve.

A particle collider encircling the moon could reach an energy of 14 quadrillion electron volts, physicists report June 6 at arXiv.org. That's about 1,000 times the energy of the world's biggest particle accelerator, the Large Hadron Collider, or LHC, at CERN near Geneva.

It's not an idea that anyone expects will become reality anytime soon, says particle physicist James Beacham of Duke University. Instead, he and physicist Frank Zimmermann of CERN considered the possibility "primarily for fun." But future physicists could potentially build a collider on the moon, Beacham says. Such a fantastical machine would probably be buried under the moon's surface to avoid wild temperature swings, the researchers say, and could be powered by solar panels.

To understand how the laws of physics work at energies higher than that of the LHC, scientists will need bigger accelerators (*SN: 2/16/19, p. 14*). The proposed Earth-based Future Circular Collider would be 100 kilometers in circumference, dwarfing the LHC's 27-kilometer ring. A collider encircling the moon would be about 11,000 kilometers around.

While building a collider that big on Earth might be possible, it could displace people who live in its path — not an issue on the moon. But, like other proposed projects that could alter the moon's appearance (*SN: 6/8/19, p. 4*), the idea raises thorny questions about who gets to decide the fate of Earth's companion, Beacham acknowledges. Those questions will presumably be left for future generations to sort out. — *Emily Conover*

Can trees save the world?

Lately, society has been putting a lot of pressure on trees to get us out of the climate change emergency we're in. There's no doubt that trees make life better in many respects, but there are right ways and plenty of wrong ways to protect and grow the forests.

The Promise and Pitfalls of Trees

Massive planting projects need much more planning and follow-through to counter climate change

By Carolyn Gramling

Trees are symbols of hope, life and transformation. They're also increasingly touted as a straightforward, relatively inexpensive, ready-for-prime-time solution to climate change.

When it comes to removing human-caused emissions of the greenhouse gas carbon dioxide from Earth's atmosphere, trees are a big help. Through photosynthesis, trees pull the gas out of the air to help grow their leaves, branches and roots. Forest soils can also sequester vast reservoirs of carbon.

Earth holds, by one estimate, as many as 3 trillion trees. Enthusiasm is growing among governments, businesses and individuals for ambitious projects to plant billions, even a trillion more. Such massive tree-planting projects, advocates say, could do two important things: help offset current emissions and also draw out CO_2 emissions that have lingered in the atmosphere for decades or longer.

Even in the politically divided United States, large-scale tree-planting projects have broad bipartisan support, according to a spring 2020 poll by the Pew Research Center. And over the last decade, a diverse garden of tree-centric proposals — from planting new seedlings to promoting natural regrowth of degraded forests to blending trees with crops and pasturelands — has sprouted across the international political landscape.

Trees "are having a bit of a moment right now," says Joe Fargione, an ecologist with The Nature Conservancy who is based in Minneapolis. It helps that everybody likes trees. "There's no anti-tree lobby. [Trees] have lots of benefits for people. Not only do they store carbon, they help provide clean air, prevent soil erosion, shade and shelter homes to reduce energy costs and give people a sense of well-being."

Conservationists are understandably eager to harness this enthusiasm to combat climate change. "We're tapping into the zeitgeist," says Justin Adams, executive director of the Tropical Forest Alliance at the World Economic Forum, an international nongovernmental organization based in Geneva. In January 2020, the World Economic Forum launched the One Trillion Trees Initiative, a global movement to grow, restore and conserve trees around the planet. One trillion is also the target for other organizations that coordinate global forestation projects, such as Plant-for-the-Planet's Trillion Tree Campaign and Trillion Trees, a partnership of the World Wildlife Fund, the Wildlife Conservation Society and other conservation groups.

Yet, as global eagerness for adding more trees grows, some scientists are urging caution. Before moving forward, they say, such massive tree projects must address a range of scientific, political, social and economic concerns. Poorly designed projects that don't address these issues could do more harm than good, the researchers say, wasting money as well as political and public goodwill. The concerns are myriad: There's too much focus on numbers of seedlings planted, and too little time spent on how to keep the trees alive in the long term, or in working with local communities. And there's not enough emphasis on how different types of forests sequester very different amounts of carbon. There's too much talk about trees, and not enough about other carbon-storing ecosystems.

"There's a real feeling that ... forests and trees are just the idea we can use to get political support" for many, perhaps more complicated, types of landscape restoration initiatives, says Joseph Veldman, an ecologist at Texas A&M University in College Station. But that can lead to all kinds of problems, he adds. "For me, the devil is in the details."

3 trillion
Estimated number of trees on Earth

The root of the problem

The pace of climate change is accelerating into the realm of emergency, scientists say. Over the last 200 years, human-caused emissions of greenhouse gases, including CO_2 and methane, have raised the average temperature of the planet by about 1 degree Celsius (*SN: 12/22/18 & 1/5/19, p. 18*).

The litany of impacts of this heating is familiar by now. Earth's poles are rapidly shedding ice, which raises sea levels; the oceans are heating up, threatening fish and food security. Tropical storms are becoming rainier and lingering longer, and out of control wildfires are blazing from the Arctic to Australia (*SN: 12/19/20 & 1/2/21, p. 32*).

The world's oceans and land-based ecosystems, such as forests, absorb about half of the carbon emissions from fossil fuel burning and other industrial activities. The rest goes into the atmosphere. So "the majority of the solution to climate change will need to come from reducing our emissions," Fargione says. To meet climate targets set by the 2015 Paris Agreement, much deeper and more painful cuts in emissions than nations have pledged so far will be needed in the next 10 years.

OPPOSITE PAGE: © SANTIAGO URQUIJO/MOMENT/GETTY IMAGES PLUS

But increasingly, scientists warn that reducing emissions alone won't be enough to bring Earth's thermostat back down. "We really do need an all-hands-on-deck approach," Fargione says. Specifically, researchers are investigating ways to actively remove that carbon, known as negative emissions technologies. Many of these approaches, such as removing CO_2 directly from the air and converting it into fuel, are still being developed.

But trees are a ready kind of negative emissions "technology," and many researchers see them as the first line of defense. In its January 2020 report, "CarbonShot," the World Resources Institute, a global nonprofit research organization, suggested that large and immediate investments in reforestation within the United States will be key for the country to have any hope of reaching carbon neutrality — in which ongoing carbon emissions are balanced by carbon withdrawals — by 2050. The report called for the U.S. government to invest $4 billion a year through 2030 to support tree restoration projects across the United States. Those efforts would be a bridge to a future of, hopefully, more technologies that can pull large amounts of carbon out of the atmosphere.

The numbers game

Earth's forests absorb, on average, 16 billion metric tons of CO_2 annually, researchers reported in the March *Nature Climate Change*. But human activity can turn forests into sources of carbon: Thanks to land clearing, wildfires and the burning of wood products, forests also emit an estimated 8.1 billion tons of the gas back to the atmosphere.

That leaves a net amount of 7.6 billion tons of CO_2 absorbed by forests per year — roughly a fifth of the 36 billion tons of CO_2 emitted by humans in 2019. Deforestation and forest degradation are rapidly shifting the balance. Forests in Southeast Asia now emit more carbon than they absorb due to clearing for plantations and uncontrolled fires. The Amazon's forests may flip from carbon sponge to carbon source by 2050, researchers say (*SN Online: 1/10/20*). The priority for slowing climate change, many agree, should be saving the trees we have (see Page 24).

Just how many more trees might be mustered for the fight is unclear, however. In 2019, Thomas Crowther, an ecologist at ETH Zurich, and his team estimated in *Science* that around the globe, there are 900 million hectares of land — an area about the size of the United States — available for planting new forests and reviving old ones (*SN: 8/17/19, p. 5*). That land could hold over a trillion more trees, the team claimed, which could trap about 206 billion tons of carbon over a century.

That study, led by Jean-Francois Bastin, then a postdoc in Crowther's lab, was sweeping, ambitious and hopeful. Its findings spread like wildfire through media, conservationist and political circles. "We were in New York during Climate Week [2019], and everybody's talking about this paper," Adams recalls. "It had just popped into people's consciousness, this unbelievable technology solution called the tree."

To channel that enthusiasm, the One Trillion Trees Initiative incorporated the study's findings into its mission statement, and countless other tree-planting efforts have cited the report.

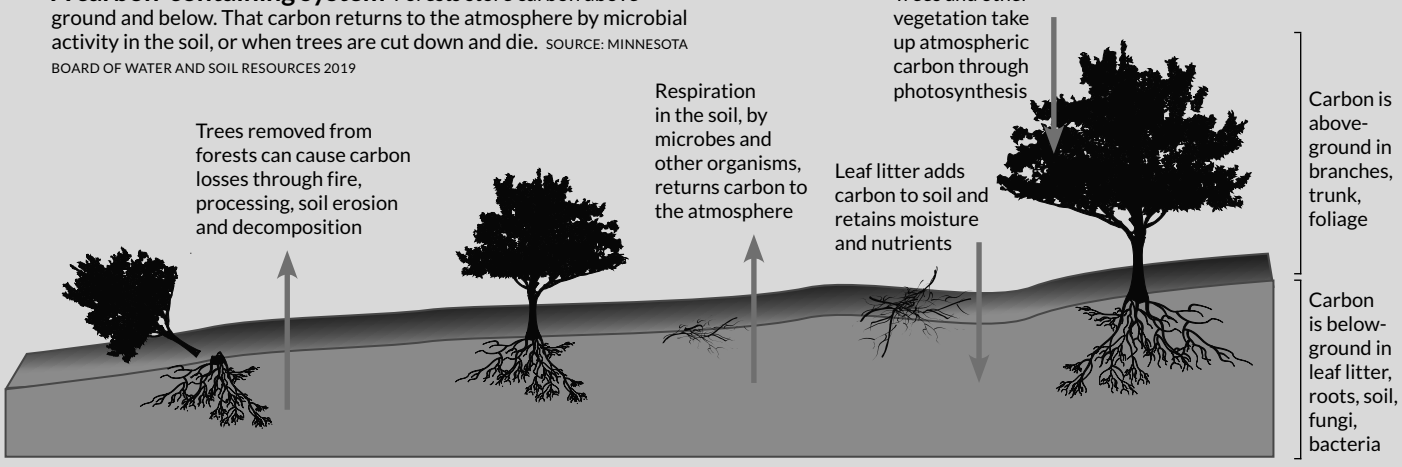
But critics say the study is deeply flawed, and that its accounting — of potential trees, of potential carbon uptake — is not only sloppy, but dangerous. In 2019, *Science* published five separate responses outlining numerous concerns. For example, the study's criteria for "available" land for tree planting were too broad, and the carbon accounting was inaccurate because it assumes that new tree canopy cover equals new carbon storage. Savannas and natural grasslands may have relatively few trees, critics noted, but these regions already hold plenty of carbon in their soils. When that carbon is accounted for, the carbon uptake benefit from planting trees drops to perhaps a fifth of the original estimate.

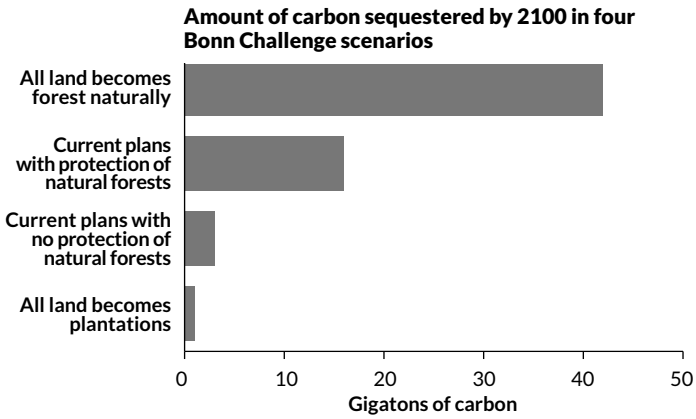
There's also the question of how forests themselves can affect the climate. Adding trees to snow-covered regions, for example, could increase the absorption of solar radiation, possibly leading to warming.

"Their numbers are just so far from anything reasonable," Veldman says. And focusing on the number of trees planted

T. TIBBITTS

A carbon-containing system Forests store carbon aboveground and below. That carbon returns to the atmosphere by microbial activity in the soil, or when trees are cut down and die. SOURCE: MINNESOTA BOARD OF WATER AND SOIL RESOURCES 2019





Levels of protection The Bonn Challenge aims to globally reforest 350 million hectares of land. Allowing all to regrow naturally would sequester 42 gigatons of carbon by 2100. Pledges of 43 tropical and subtropical nations that joined by 2019 — a mix of plantations and natural regrowth — would sequester 16 gigatons of carbon. If some of the land is later converted to biofuel plantations, sequestration is 3 gigatons. With only plantations, carbon storage is 1 gigaton. SOURCE: S.L. LEWIS *ET AL/NATURE* 2019

also sets up another problem, he adds — an incentive structure that is prone to corruption. "Once you set up the incentive system, behaviors change to basically play that game."

Adams acknowledges these concerns. But, the One Trillion Trees Initiative isn't really focused on "the specifics of the math," he says, whether it's the number of trees or the exact amount of carbon sequestered. The goal is to create a powerful climate movement to "motivate a community behind a big goal and a big vision," he says. "It could give us a fighting chance to get restoration right."

Other nonprofit conservation groups, like the World Resources Institute and The Nature Conservancy, are trying to walk a similar line in their advocacy. But some scientists are skeptical that governments and policy makers tasked with implementing massive forest restoration programs will take note of such nuances.

"I study how government bureaucracy works," says Forrest Fleischman, who researches forest and environmental policy at the University of Minnesota in St. Paul. Policy makers, he says, are "going to see 'forest restoration,' and that means planting rows of trees. That's what they know how to do."

Counting carbon

How much carbon a forest can draw from the atmosphere depends on how you define "forest." There's reforestation — restoring trees to regions where they used to be — and afforestation — planting new trees where they haven't historically been. Reforestation can mean new planting, including crop trees; allowing forests to regrow naturally on lands previously cleared for agriculture or other purposes; or blending tree cover with croplands or grazing areas (see Page 30).

In the past, the carbon uptake potential of letting forests regrow naturally was underestimated by 32 percent, on average — and by as much as 53 percent in tropical forests, according to a 2020 study in *Nature*. Now, scientists are calling for more attention to this forestation strategy.

If it's just a matter of what's best for the climate, natural forest regrowth offers the biggest bang for the buck, says Simon Lewis, a forest ecologist at University College London. Single-tree commercial crop plantations, on the other hand, may meet the technical definition of a "forest" — a certain concentration of trees in a given area — but factor in land clearing to plant the crop and frequent harvesting of the trees, and such plantations can actually release more carbon than they sequester.

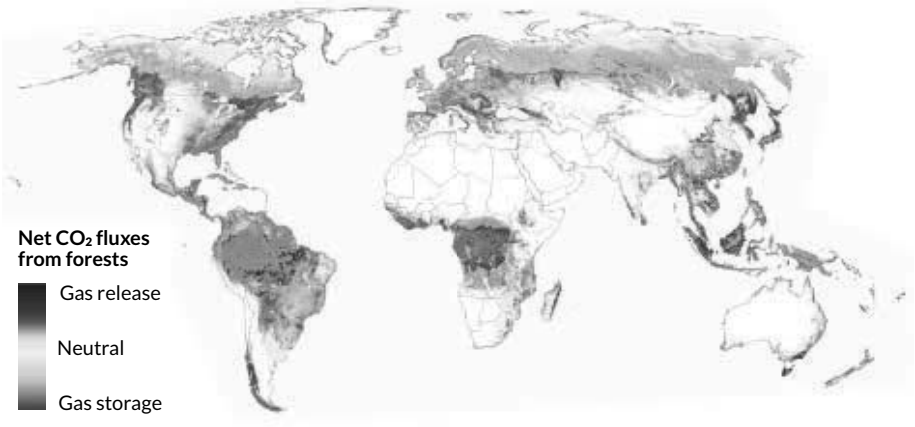
Comparing the carbon accounting between different restoration projects becomes particularly important in the framework of international climate targets and challenges. For example, the 2011 Bonn Challenge is a global project aimed at restoring 350 million hectares by 2030. As of 2020, 61 nations had pledged to restore a total of 210 million hectares of their lands. The potential carbon impact of the stated pledges, however, varies widely depending on the specific restoration plans.

In a 2019 study in *Nature*, Lewis and his colleagues estimated that if all 350 million hectares were allowed to regrow natural forest, those lands would sequester about 42 billion metric tons (gigatons in chart above) of carbon by 2100. Conversely, if the land were to be filled with single-tree commercial crop plantations, carbon storage drops to about 1 billion metric tons. And right now, plantations make up a majority of the restoration plans submitted under the Bonn Challenge.

Striking the right balance between offering incentives to landowners to participate while also placing certain restrictions remains a tricky and long-standing challenge, not just for combating the climate emergency but also for trying to

Forests in flux While global forests were a net carbon sink of about 7.6 gigatons of carbon dioxide per year from 2001 to 2019, forests in areas such as Southeast Asia and parts of the Amazon began releasing more carbon than they store.

Net annual average contribution of carbon dioxide from Earth's forests, 2001–2019



FROM TOP: T. TIBBITTS; N.L. HARRIS *ET AL/NATURE CLIMATE CHANGE* 2021

preserve biodiversity (*SN: 8/1/20, p. 18*). Since 1974, Chile, for example, has been encouraging private landowners to plant trees through subsidies. But landowners are allowed to use these subsidies to replace native forestlands with profitable plantations. As a result, Chile's new plantings not only didn't increase carbon storage, they also accelerated biodiversity losses, researchers reported in the September 2020 *Nature Sustainability*.

The reality is that plantations are a necessary part of initiatives like the Bonn Challenge, because they make landscape restoration economically viable for many nations, Lewis says. "Plantations can play a part, and so can agroforestry as well as areas of more natural forest," he says. "It's important to remember that landscapes provide a whole host of services and products to people who live there."

But he and others advocate for increasing the proportion of forestation that is naturally regenerated. "I'd like to see more attention on that," says Robin Chazdon, a forest ecologist affiliated with the University of the Sunshine Coast in Australia as well as with the World Resources Institute. Naturally regenerated forests could be allowed to grow in buffer regions between farms, creating connecting green corridors that could also help preserve biodiversity, she says. And "it's certainly a lot less expensive to let nature do the work," Chazdon says.

Indeed, massive tree-planting projects may also be stymied by pipeline and workforce issues. Take seeds: In the United States, nurseries produce about 1.3 billion seedlings per year, Fargione and colleagues calculated in a study reported February 4 in *Frontiers in Forests and Global Change*. To support a massive tree-planting initiative, U.S. nurseries would need to at least double that number.

Trees can buy time for tech testing

If done right, planting trees might give researchers time to develop some of these carbon-capture technologies.

Bioenergy with carbon capture and sequestration
Plant biomass is used to produce electricity, fuel or heat. Any CO_2 released is captured and stored.

Direct air capture
Chemical processes that capture CO_2 from ambient air and concentrate it, so that it can be injected into a storage reservoir.

Carbon mineralization
Through chemical reactions, CO_2 from the atmosphere becomes trapped in existing rock.

Geologic sequestration
CO_2 is captured and injected into deep underground formations.

A tree-planting report card

From China to Turkey, countries around the world have launched enthusiastic national tree-planting efforts. And many of them have become cautionary tales.

China kicked off a campaign in 1978 to push back the encroaching Gobi Desert, which has become the fastest-growing desert on Earth due to a combination of mass deforestation and overgrazing, exacerbated by high winds that drive erosion. China's Three-North Shelter Forest Program, nicknamed the Great Green Wall, aims to plant a band of trees stretching 4,500 kilometers across the northern part of the country. The campaign has involved millions of seeds dropped from airplanes and millions more seedlings planted by hand. But a 2011 analysis suggested that up to 85 percent of the plantings had failed because the nonnative species chosen couldn't survive in the arid environments they were plopped into.

More recently, Turkey launched its own reforestation effort. On November 11, 2019, National Forestation Day, volunteers across the country planted 11 million trees at more than 2,000 sites. In Turkey's Çorum province, 303,150 saplings were planted in a single hour, setting a new world record.

Within three months, however, up to 90 percent of the new saplings inspected by Turkey's agriculture and forestry trade union were dead, according to the union's president, Şükrü Durmuş, speaking to the *Guardian* (Turkey's minister of agriculture and forestry denied that this was true). The saplings, Durmuş said, died due to a combination of insufficient water and because they were planted at the wrong time of year, and not by experts.

Some smaller-scale efforts also appear to be failing, though less spectacularly. Tree planting has been ongoing for decades in the Kangra district of Himachal Pradesh in northern India, says Eric Coleman, a political scientist at Florida State University in Tallahassee, who's been studying the outcomes. The aim is to increase the density of the local forests and provide additional forest benefits for communities nearby, such as wood for fuel and fodder for grazing animals. How much money was spent isn't known, Coleman says, because there aren't records of how much was paid for seeds. "But I imagine it was in the millions and millions of dollars."

Coleman and his colleagues analyzed satellite images and interviewed members of the local communities. They found that the tree planting had very little impact one way or the other. Forest density didn't change much, and the surveys suggested that few households were gaining benefits from the planted forests, such as gathering wood for fuel, grazing animals or collecting fodder.

T. TIBBITTS

A woman places straw in March 2019 to fix sand in place before planting trees at the edge of the Gobi Desert in China's Minqin County. Her work is part of a private tree-planting initiative that dovetails with the government's decades-long effort to build a "green wall" to hold back the desert.

WANG HE/GETTY IMAGES PLUS

But massive tree-planting efforts don't have to fail. "It's easy to point to examples of large-scale reforestation efforts that weren't using the right tree stock, or adequately trained workforces, or didn't have enough investment in ... postplanting treatments and care," Fargione says. "We ... need to learn from those efforts."

Speak for the trees

Forester Lalisa Duguma of World Agroforestry in Nairobi, Kenya, and colleagues explored some of the reasons for the very high failure rates of these projects in a working paper in 2020. "Every year there are billions of dollars invested [in tree planting], but forest cover is not increasing," Duguma says. "Where are those resources going?"

In 2019, Duguma raised this question at the World Congress on Agroforestry in Montpellier, France. He asked the audience of scientists and conservationists: "How many of you have ever planted a tree seedling?" To those who raised their hands, he asked, "Have they grown?"

Some respondents acknowledged that they weren't sure. "Very good! That's what I wanted," he told them. "We invest a lot in tree plantings, but we are not sure what happens after that."

It comes down to a deceptively simple but "really fundamental" point, Duguma says. "The narrative has to change — from tree planting to tree growing."

The good news is that this point has begun to percolate through the conservationist world, he says. To have any hope of success, restoration projects need to consider the best times of year to plant seeds, which seeds to plant and where, who will care for the seedlings as they grow into trees, how that growth will be monitored, and how to balance the economic and environmental needs of people in developing countries where the trees might be planted.

"That is where we need to capture the voice of the people," Duguma says. "From the beginning."

Even as the enthusiasm for tree planting takes root in the policy world, there's a growing awareness among researchers and conservationists that local community engagement must be built into these plans; it's indispensable to their success.

"It will be almost impossible to meet these targets we all care so much about unless small farmers and communities benefit more from trees," as David Kaimowitz of the United Nations' Food and Agriculture Organization wrote March 19 in a blog post for the London-based nonprofit International Institute for Environment and Development.

For one thing, farmers and villagers managing the land need incentives to care for the plantings and that includes having clear rights to the trees' benefits, such as food or thatching or grazing. "People who have insecure land tenure don't plant trees," Fleischman says.

Fleischman and others outlined many of the potential social and economic pitfalls of large-scale tree-planting projects last November in *BioScience*. Those lessons boil down to this, Fleischman says: "You need to know something about the place ... the political dynamics, the social dynamics.... It's going to be very different in different parts of the world."

The old cliché — think globally, act locally — may offer the best path forward for conservationists and researchers trying to balance so many different needs and still address climate change.

"There are a host of sociologically and biologically informed approaches to conservation and restoration that ... have virtually nothing to do with tree planting," Veldman says. "An effective global restoration agenda needs to encompass the diversity of Earth's ecosystems and the people who use them." ■

Explore more

- Forrest Fleischman *et al.* "Pitfalls of tree planting show why we need people-centered natural climate solutions." *BioScience*. November 2020.

Conserving natural forests is a double win for trapping carbon and saving rich biodiversity. Forests matter to (clockwise from top left) humans (with a *Treculia* fruit), *Phromnia* planthoppers and mouse lemurs.

First, Protect Today's Forests

To slow the ravages of climate change, defend against deforestation

By Susan Milius

ALL: COURTESY OF THE STAFF OF THE MISSOURI BOTANICAL GARDEN, ST. LOUIS AND MADAGASCAR

Between a death and a burial was hardly the best time to show up in a remote village in Madagascar to make a pitch for forest protection. Bad timing, however, turned out to be the easy problem.

This forest was the first one that botanist Armand Randrianasolo had tried to protect. He's the first native of Madagascar to become a Ph.D. taxonomist at Missouri Botanical Garden, or MBG, in St. Louis. So he was picked to join a 2002 scouting trip to choose a conservation site.

Other groups had already come into the country and protected swaths of green, focusing on "big forests; big, big, *big*!" Randrianasolo says. Preferably forests with lots of big-eyed, fluffy lemurs to tug heartstrings elsewhere in the world.

The Missouri group, however, planned to go small and to focus on the island's plants, legendary among botanists but less likely to be loved as a stuffed cuddly. The team zeroed in on fragments of humid forest that thrive on sand along the eastern coast. "Nobody was working on it," he says.

As the people of the Agnalazaha forest were mourning a member of their close-knit community, Randrianasolo decided to pay his respects: "I wanted to show that I'm still Malagasy," he says. He had grown up in a seaside community to the north.

The village was filling up with visiting relatives and acquaintances, a great chance to talk with many people in the region. The deputy mayor conceded that after a morning visit to the bereaved, Randrianasolo and MBG's Chris Birkinshaw could speak in the afternoon with anyone wishing to gather at the roofed marketplace.

The two scientists didn't get the reception they'd hoped for. Their pitch to help the villagers conserve their forest while still serving people's needs met protests from the crowd: "You're lying!"

The community was still upset about a different forest that outside conservationists had protected. The villagers had assumed they would still be able to take trees for lumber, harvest their medicinal plants or sell other bits from the forest during cash emergencies. They were wrong. That place was now off-limits. People caught doing any of the normal things a forest community does would be considered poachers. When MBG proposed conserving yet more land, residents weren't about to get tricked again. "This is the only forest we have left," they told the scientists.

Finding some way out of such clashes to save existing forests has become crucial for fighting climate change. Between 2001 and 2019, the planet's forests trapped an estimated 7.6 billion metric tons of carbon dioxide a year, an international team reported in *Nature Climate Change* in March (see Page 19). That rough accounting suggests trees may capture about one and a half times the annual emissions of the United States, one of the largest global emitters.

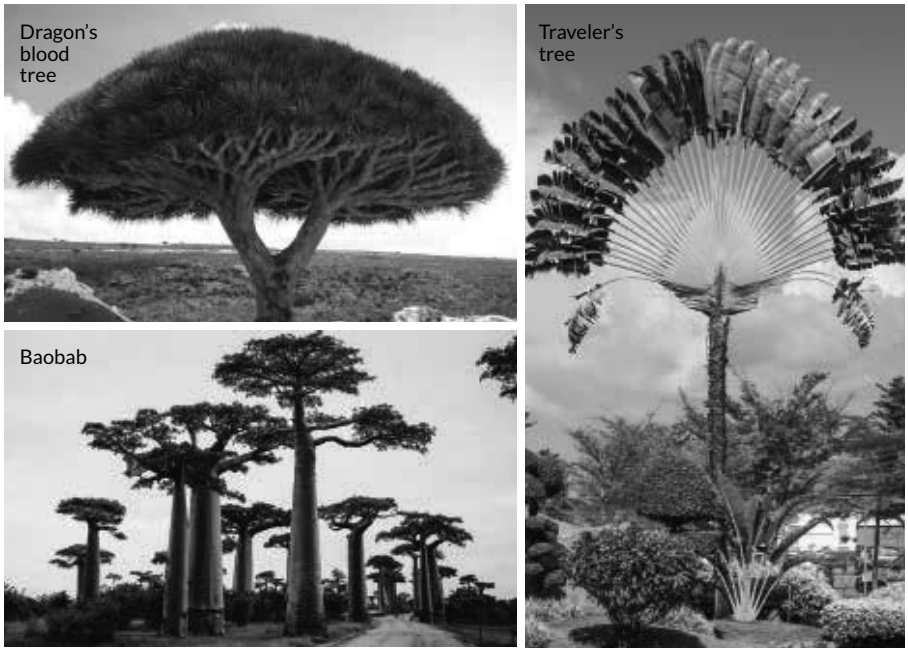
Planting trees by the millions and trillions is basking in round-the-world enthusiasm right now. Yet saving the forests we already have ranks higher in priority and in payoff, say a variety of scientists.

How to preserve forests may be a harder question than why. Success takes strong legal protections with full government support. It also takes a village, literally. A forest's most intimate neighbors must wholeheartedly want it saved, one generation after another. That theme repeats in places as different as rural Madagascar and suburban New Jersey.

Overlooked and underprotected

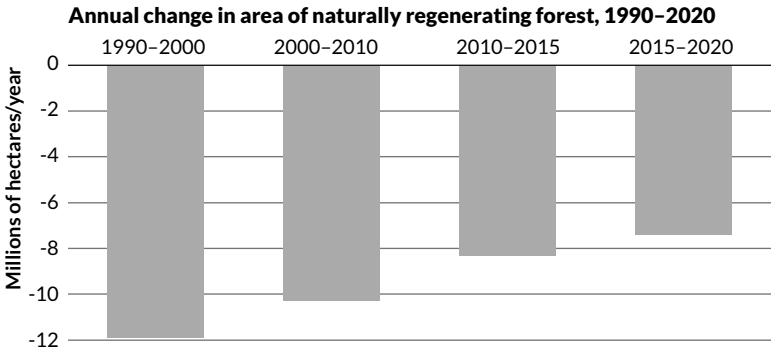
First a word about trees themselves. This *Science News* issue leans in with a magnifying glass to look at trees as a way to capture carbon and fight climate change. But trees are much more than useful wooden objects that happen to be leafy, self-manufacturing and great shade for picnics.

"Plant blindness," as it has been called, reduces trees and other photosynthetic organisms to background, lamented botanist Sandra Knapp in a 2019 article in the journal *Plants, People, Planet*. For instance, show people a picture with a squirrel in a forest. They'll likely say something like "cute



Joy trees A green lollipop shape may be the common symbol for a tree, but real forms vary widely. Branches of a *Dracaena cinnabari* dragon's blood tree from Yemen repeatedly bifurcate in even Y-splits. *Ravenala* traveler's tree, widely grown but native only to Madagascar, and one of the island's *Adansonia* baobabs, have their own unique looks.

CLOCKWISE FROM TOP LEFT: BORIS KHVOSTICHENKO/WIKIMEDIA COMMONS (CC BY-SA 4.0); © CEPHOTO, UWE ARANAS/WIKIMEDIA COMMONS (CC BY-SA 3.0); THEME INN/UNSPLASH



Forest loss down Destruction of the world's natural forests continues, though rates have been slowing. The target of two international agreements — to halve the previous decade's rate by 2020 — has not been met. SOURCE: FAO, 2020

squirrel." Not "nice-size beech tree, and is that a young black oak with a cute squirrel on it?"

This tunnel vision also excludes invertebrates, argues Knapp, of the Natural History Museum in London, complicating efforts to save nature. These half-seen forests, natural plus human-planted, now cover close to a third of the planet's land, according to the 2020 version of *The State of the World's Forests* report from the United Nation's Food and Agriculture Organization. Yet a calculation based on the report's numbers says that over the last 10 years, net tree cover vanished at an average rate of about 12,990 hectares — a bit more than the area of San Francisco — every day.

This is an improvement over the previous decades, the report notes. In the 1990s, deforestation, on average, destroyed about 1.75 San Francisco equivalents of forest every day.

Trees were the planet's skyscrapers, many rising to great heights, hundreds of millions of years before humans began piling stone upon stone to build their own. Trees reach their stature by growing and then killing their innermost core of tissue. The still-living outer rim of the tree uses its ever-increasing inner ghost architecture as plumbing pipes that can function as long as several human lifetimes. And tree sex lives, oh my. Plants invented "steamy but not touchy" long before the Victorian novel — much flowering, perfuming and maybe green yearning, all without direct contact of reproductive organs. Just a dusting of pollen wafted on a breeze or delivered by a bee.

To achieve the all-important goal of cutting global emissions, saving the natural forests already in the ground must be a priority, 14 scientists from around the world wrote in the April *Global Change Biology*. "Protect existing forests first," coauthor Kate Hardwick of Kew Gardens in London said during a virtual conference on reforestation in February. That priority also gives the planet's magnificent biodiversity a better chance at surviving. Trees can store a lot of carbon in racing to the sky. And size and age matter because trees add carbon over so much of their architecture, says ecologist David Mildrexler with Eastern Oregon Legacy Lands at the Wallowology Natural History Discovery Center in Joseph. Trees don't just start new growth at twigs tipped with unfurling baby leaves. Inside the branches, the trunk and big roots, an actively growing sheath surrounds the inner ghost plumbing. Each season, this whole sheath adds a layer of carbon-capturing tissue from root to crown.

"Imagine you're standing in front of a really big tree — one that's so big you can't even wrap your arms all the way around, and you look up the trunk," Mildrexler says. Compare that sky-touching vision to the area covered in a year's growth of some sapling, maybe three fingers thick and human height. "The difference is, of course, just huge," he says.

Big trees may not be common, but they make an outsize difference in trapping carbon, Mildrexler and colleagues have found. In six Pacific Northwest national forests, only about 3 percent of all the trees in the study, including ponderosa pines, western larches and three other major species, reached full-arm-hug size (at least 53.3 centimeters in diameter). Yet this 3 percent of trees stored 42 percent of the aboveground

Near Madagascar's Analavelona sacred forest, taxonomist Armand Randrianasolo (blue cap) joins (from left) Miandry Fagnarena, Rehary, and Tefy Andriamihajarivo to collect a surprising new species in the mango family (green leaves at front of image). The *Spondias tefyi*, named for Tefy and his efforts to protect the island's biodiversity, is the first wild relative of the popular hog plum found outside of South America or Asia.

FROM TOP: C. CHANG; COURTESY OF THE STAFF OF THE MISSOURI BOTANICAL GARDEN, ST. LOUIS AND MADAGASCAR

Saddler's Woods, with a scrap of old-growth forest, has survived in the rush of development in suburban New Jersey thanks to generations of dedicated forest lovers.

SADDLER'S WOODS CONSERVATION ASSOCIATION

carbon there, the team reported in 2020 in *Frontiers in Forests and Global Change*. An earlier study, with 48 sites worldwide and more than 5 million tree trunks, found that the largest 1 percent of trees store about 50 percent of the aboveground carbon-filled biomass.

Plant paradise

The island nation of Madagascar was an irresistible place for the Missouri Botanical Garden to start trying to conserve forests. Off the east coast of Africa, the island stretches more than the distance from Savannah, Ga., to Toronto, and holds more than 12,000 named species of trees, other flowering plants and ferns. Madagascar "is absolute nirvana," says MBG botanist James S. Miller, who has spent decades exploring the island's flora.

Just consider the rarities. Of the eight known species of baobab trees, which raise a fat trunk to a cartoonishly spindly tuft of little branches on top, six are native to Madagascar. Miller considers some 90 percent of the island's plants as natives unique to the country. "It wrecks you" for botanizing elsewhere, Miller says.

He was rooting for his MBG colleagues Randrianasolo and Birkinshaw in their foray to Madagascar's Agnalazaha forest. Several months after getting roasted as liars by residents, the two got word that the skeptics had decided to give protection a chance after all.

The Agnalazaha residents wanted to make sure, however, that the Missouri group realized the solemnity of their promise. Randrianasolo had to return to the island for a ceremony of calling the ancestors as witnesses to the new partnership and marking the occasion with the sacrifice of a cow. A pact with generations of deceased residents may be an unusual form of legal involvement, but it carried weight. Randrianasolo bought the cow.

Randrianasolo looked for ways to be helpful. MBG worked on improving the village's rice yields, and supplied starter batches of vegetable seeds for expanding home gardens. The MBG staff helped the forest residents apply for conservation funds from the Malagasy government. A new tree nursery gave villagers an alternative to cutting timber in the forest. The nursery also meant some jobs for local people, which further improved relationships.

The MBG staff now works with Malagasy communities to preserve forests at 11 sites dotted in various ecosystems in Madagascar. Says Randrianasolo: "You have to be patient."

Today, 19 years after his first visit among the mourners, Agnalazaha still stands.

Saving forests is not a simple matter of just meeting basic needs of people living nearby, says political scientist Nadia Rabesahala Horning of Middlebury College in Vermont, who published *The Politics of Deforestation in Africa* in 2018. Her Ph.D. work, starting in the late 1990s, took her to four remote forests in her native Madagascar. The villagers around each forest followed different rules for harvesting timber, finding places to graze livestock and collecting medicinal plants.

Three of the forests shrank, two of them rapidly, over the decade. One, called Analavelona, however, barely showed any change in the aerial views Horning used to look for fraying forests.

The people living around Analavelona revered

Tied with yarn to nearly 3,000 trees in a Maryland forest, tags displayed the names of the people lost on 9/11. The memorial, organized by ecologist Joan Maloof who runs the Old-Growth Forest Network, helped protect a patch of woods where people could go for solace and meditation.

it as a sacred place where their ancestors dwelled. Living villagers made offerings before entering, and cut only one kind of tree, which they used for coffins.

Since then, Horning's research in Tanzania and Uganda has convinced her that forest conservation can happen only under very specific conditions, she says. The local community must be able to trust that the government won't let some commercial interest or a political heavyweight slip through loopholes to exploit a forest that its everyday neighbors can't touch. And local people must be able to meet their own needs too, including the spiritual ones.

A different kind of essential

Another constellation of old forests, on the other side of the world, sports some less-than-obvious similarities. Ecologist Joan Maloof launched the Old-Growth Forest Network in 2011 to encourage people to save the remaining scraps of U.S. old-growth forests. Her bold idea: to permanently protect one patch of old forest in each of the more than 2,000 counties in the United States where forests can grow.

She calls for strong legal measures, such as conservation easements that prevent logging, but also recognizes the need to convey the emotional power of communing with nature. One of the early green spots she and colleagues campaigned for was not old growth, but it had become one of the few left unlogged where she lived on Maryland's Eastern Shore.

She heard about Buddhist monks in Thailand who had ordained trees as monks because loggers revered the monks, so the trees were protected. A month after the 9/11 terrorist attacks, she was inspired to turn the Maryland forest into a place to remember the victims. By putting each victim's name on a metal tag and tying it to a tree, she and other volunteers created a memorial with close to 3,000 trees. The local planning commission, she suspected, would feel awkward about approving timber cutting from that particular stand. She wasn't party to their private deliberations, but the forest still stands.

As of Earth Day 2021, the network had about 125 forests around the country that should stay forests in perpetuity. Their stories vary widely, but are full of local history and political maneuvering.

In southern New Jersey, Joshua Saddler, an escaped enslaved man from Maryland, acquired part of a small forest in the mid-1880s and bequeathed it to his wife with the stipulation that it not be logged. His section was logged anyway, and the rest of the original old forest was about to meet the same fate. In 1973, high school student Doug Hefty wrote more than 80 pages on the forest's value — and delivered it to the developer. In this case, life delivered a genuine Hollywood ending. The developer relented, and scaled back the project, stopping across the street from the woods.

In 1999, however, developers once again eyed the forest, says Janet Goehner-Jacobs, who heads the Saddler's Woods Conservation Association. It took four years, but now, she and the forests' other fans have a conservation easement forbidding commercial development or logging, giving the next generation better tools to protect the forest.

Goehner-Jacobs had just moved to the area and fallen in love with that 10-hectare patch of green in the midst of apartment buildings and strip malls. When she first happened upon the forest and found the old-growth section, "I just instinctively knew I was seeing something very different." ■

In 1973, high school freshman Doug Hefty wrote more than 80 pages about the value of Saddler's Woods in Haddon Township, N.J. His typed report, with its handmade cover, played a dramatic role in saving the forest.

Explore more

- Alice Di Sacco *et al*. "Ten golden rules for reforestation to optimize carbon sequestration, biodiversity recovery and livelihood benefits." *Global Change Biology*. April 2021.

FROM TOP: FRIENDS OF THE FOREST, SALISBURY; SADDLER'S WOODS CONSERVATION ASSOCIATION

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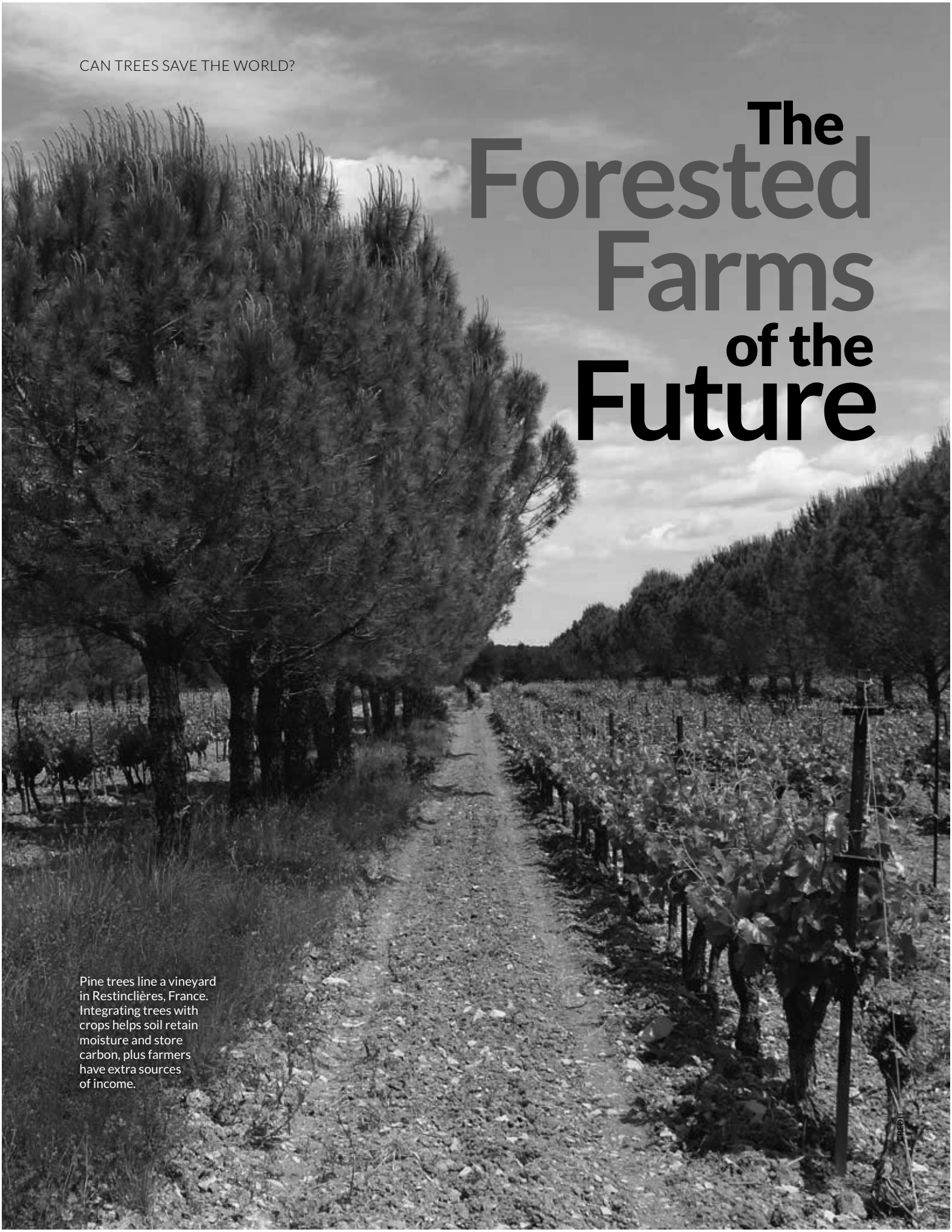
The Forested Farms of the Future



Pine trees line a vineyard in Restinclières, France. Integrating trees with crops helps soil retain moisture and store carbon, plus farmers have extra sources of income.

CREDIT

Adding trees amid crops can boost food production, store carbon and save species

By Jonathan Lambert

Maxwell Ochoo's first attempt at farming was a dismal failure.

In Ochieng Odiere, a village near the shores of Kenya's Lake Victoria, "getting a job is a challenge," the 34-year-old says. To earn some money and help feed his family, he turned to farming. In 2017, he planted watermelon seeds on his 0.7-hectare plot.

Right when the melons were set to burst from their buds and balloon into juicy orbs, a two-month dry spell hit, and Ochoo's fledgling watermelons withered. He lost around 70,000 Kenyan shillings, or about $650.

Ochoo blamed the region's loss of tree cover for the long dry spells that had become more common. Unshielded from the sun, the soil baked, he says.

In 2018, Ochoo and some neighbors decided to plant trees on public lands and small farms. With the help of nonprofit groups, the community planted hundreds of trees, turning some of the barren hillsides green. On his own farm, Ochoo now practices alley cropping, in which he plants millet, onions, sweet potatoes and cassava between rows of fruit and other trees.

The trees provide shade and shelter to the crops, and their deeper root systems help the soil retain moisture. A few times a week in the growing season, Ochoo takes papayas, some as big as his head, to market, bringing home the equivalent of about $25 each time.

And the fallen leaves of the new *Calliandra* trees provide fodder for Ochoo's five cows. He also discovered that he could grind up the fernlike leaves as a dietary supplement for the tilapia he grows in a small pond. He now spends less on fish food, and the tilapia grow much faster than his neighbors' fish, he says.

Today, nearly everything Ochoo's family eats comes from the farm, with plenty left over to sell at market. "Whether during dry spell or rainy season, my land is not bare," he says, "there's something that can sustain the family."

Ochoo's tree-filled farm represents what many scientists hope will be farming's future. The present reality, where fields are often cleared of trees to raise livestock or plant row after row of single crops, called monocultures, is running out of room.

About half of all habitable land on Earth is devoted to growing food. More than 30 percent of forests have been cleared worldwide, and another 20 percent degraded, largely to make room for raising livestock and growing crops. By 2050, to feed a growing population, croplands will have to increase by 26 percent, an area the size of India, researchers estimate.

Humans' collective hunger drives the twin ecological crises of climate change and biodiversity loss. Cutting down trees to make room for crops and livestock releases carbon into the atmosphere and erases the natural habitats that support so many species (*SN: 1/30/21, p. 5*).

Humankind is in danger of crossing a planetary boundary with unpredictable consequences, says landscape ecologist Tobias Plieninger of Germany's University of Kassel and University of Göttingen. As land continues to be cleared for agriculture, "there's high pressure ... to shift toward more sustainable land use practices."

> Approximately half of all habitable land on Earth is devoted to growing food.

Farmers like Ochoo, who intentionally blend crops, trees and livestock, a practice loosely called agroforestry, offer a more sustainable way forward. Agroforestry may not work in every circumstance, "but it has great potential," Plieninger says, for working toward food production and conservation goals on the same land.

Integrating trees onto farms may seem like a recipe for lower yields, as trees would replace

Maxwell Ochoo eats a juicy papaya from his farm in Kenya. Papaya trees help keep moisture in the soil in drier times, benefiting the crops he grows between the trees.

OPPOSITE PAGE: AGFORWARD PROJECT/FLICKR (CC BY-NC-SA 2.0); THIS PAGE: M. OCHOO

some crops. But such mixing can actually squeeze more food from a given plot of land than when plants are grown separately, Plieninger says. In Europe, blended farms that grow wheat or sunflowers between rows of wild cherry and walnut trees, for example, can produce up to 40 percent more than monocultures of the same crops for a given area.

Agroforestry was the norm until modern agricultural methods swept the globe, especially after the Industrial Revolution and the rise of chemical fertilizers in the mid-20th century. But small farms in the tropics are still big on trees. Worldwide, about 43 percent of land used for agriculture has at least 10 percent tree cover, according to a 2016 study in *Scientific Reports*.

Increasing that percentage could have profound and wide-ranging benefits, if done right. "Trees have to be integrated [onto farms] to not create extra problems" for farmers, says Anja Gassner, a senior scientist at World Agroforestry in Bonn, Germany. And the approach looks very different depending on the region and the goals of the people who live there. What Spanish farmers need from their oak-dotted fields where pigs get fat on acorns will be different from what farmers in Ecuador want from their coffee plants growing under the cool shade of tropical inga trees.

The way agroforestry is carried out in three very different parts of the world illustrates the promises and challenges of coupling trees and crops.

43
Percent
Worldwide share of coffee grown under tree canopy in 1996

24
Percent
Worldwide share in 2010

Made in the shade

If you're enjoying a morning cup of coffee while reading this, there's a chance the beans in that brew came from farms practicing agroforestry.

Coffee plants evolved in the understory of Ethiopia's highland forests; they are well-suited to shade, says Eduardo Somarriba, an agroecologist at the Tropical Agricultural Research and Higher Education Center in Cartago, Costa Rica.

A diverse canopy of native trees can help coffee plants thrive. Certain trees pump nitrogen into the soil, removing the need for intensive fertilizer application, Somarriba says. Native vegetation suppresses weed growth, stabilizes soil and temperature, improves water retention and supports pollinating animals.

But as global thirst for coffee has grown, planting practices have shifted toward shadeless plots filled only with coffee plants that require a steady stream of chemical fertilizers. From 1996 to 2010, the worldwide share of coffee grown under a canopy of diverse trees fell from 43 percent to 24 percent, researchers reported in 2014 in *BioScience*.

Removing trees is seen as good for increasing yields, though the evidence is mixed. This focus on numbers misses the more diffuse benefits of diversifying farms, Somarriba says, especially small farms, which still produce most of the world's coffee.

"If coffee prices go down and stay low for five or six years, a small farmer will not be able to make it only from [selling] coffee," Somarriba says. But adding a mix of trees can build in economic and climate resilience, he says.

Valuable timber trees, like mahogany, can serve as savings accounts, harvested when coffee profits aren't enough. Mango, Brazil nut or acai trees can supply income, too. But not all places have well-developed markets for these goods, Somarriba says, which presents a challenge to increasing the share of coffee grown under shade.

Some conservationists are trying to boost consumer demand for shade-grown coffee by highlighting how it benefits biodiversity. The Smithsonian Migratory Bird Center, for example, grants a Bird Friendly certification to plantations with ample native tree cover and diversity, a boon for migratory birds. Certified farmers are able to charge a slightly higher price, on average 5 to 15 cents more per pound.

Migratory birds flock to such plantations. "When you're in a bird-friendly coffee farm, it kind of feels like you're in the forest," says Ruth Bennett, an ecologist at the Smithsonian Migratory Bird Center in Washington, D.C. "You hear a lot of bird calls, and it's a huge diversity of birds, including really sexy tropical species like the turquoise-browed motmot," she says.

Bird Friendly coffee plantations also appear to be good for mammals. In Mexico, Bird Friendly coffee plantations had more native wildlife, including deer and mice, than other coffee plantations, according to a 2016 study in *PLOS ONE*.

Ecosystems brimming with diverse species of plants, animals and more make the planet livable by filtering water, cycling nutrients through soils and pollinating crops. While undeveloped forest is clearly best for biodiversity, shade-grown plantations can outshine other land uses. After more than a decade, high-diversity coffee agroforestry systems in southeastern Brazil were ecologically healthier — as measured by tree canopy cover and species richness — than plots set aside for nonagricultural restoration, researchers reported in the September 2020 *Restoration Ecology*. About 90 percent of the canopy was

intact on shaded coffee plots versus about 60 percent for restored forest areas, on average.

Beyond the biodiversity benefits, Bennett says shade-grown coffee just tastes better. Under shade, coffee cherries take longer to develop, which can boost sugar content.

Time to recover

In the Shinyanga region of Tanzania, a return to traditional Indigenous practices, with a dose of modern agroforestry, helped transform what was once the "desert of Tanzania" back into productive savanna woodlands.

The region, about a five-hour drive southeast from the Serengeti, is home to the Sukuma people, traditionally agropastoralists who raised livestock in the hilly grasslands of the region, dotted with acacia and oaklike miombo trees.

But in the 1920s, the landscape began to change. The British colonial government cut back woodlands in a misguided effort to control the tsetse flies that were harming livestock and humans and to plant cash crops like cotton. In the 1960s, forest loss accelerated when the government took ownership of many homesteads. After they lost rights to harvest products from the forest, local Tanzanians had less incentive to conserve the trees.

Within a few decades, the ecosystem had degraded into dry, dusty expanses largely devoid of trees. Food, firewood and water were scarce and local livelihoods suffered, says Lalisa Duguma, a sustainability scientist at World Agroforestry, an international research agency headquarted in Nairobi, Kenya.

By the 1980s, the situation had become so dire that the Tanzanian government intervened. At first, it tried to convince local residents to plant seedlings of fast-growing exotic trees, like eucalyptus, Duguma says. But locals weren't interested in planting or tending those seedlings. In the face of this setback, experts and officials did something not always done in development projects: They listened.

Listening to locals revealed that an age-old tradition of forming *ngitilis* could be the foundation for restoration. Roughly translated as "enclosure," a *ngitili* cordons off a section of land for a year or two, allowing trees and grasses to recover, and then opening it to provide fodder for grazing animals during the dry season. "By just fencing in degraded land, the process of restoration starts," Duguma says.

Native seeds and stumps long stunted by grazing or poor soil conditions can begin to grow again, and their numbers can be supplemented with planted trees. Local institutions largely planned and monitored *ngitilis*, in accordance with traditional practices, often in collaboration with government scientists.

Rows of coffee plants are shaded by trees on this plantation in Ecuador. The trees help prevent the slopes from eroding and can be harvested to supply farmers with extra income.

MORLEY READ/ALAMY STOCK PHOTO

Year by year, the benefits of *ngitilis* slowly accrued, giving shade and fodder to livestock and wood for energy and building. Maturing trees provided fruits and supported beehives for honey production.

At the start of the restoration in the mid-1980s, there were only 600 hectares of *ngitilis* in all of the Shinyanga region. After 16 years, more than 300,000 hectares of land was restored. The return of trees in the region may have sequestered more than 20 million metric tons of carbon over 16 years (the equivalent of taking 16.7 million cars off the road for a year), according to a 2005 report by the Tanzanian government and the International Union for the Conservation of Nature. Deeper root systems bolstered soil health, and expanded tree cover cut down on wind and water erosion, halting desertification.

Ngitilis provided benefits equal to $14 per person per month, substantially more than the $8.50 an average person spends in a month in rural Tanzania, the same report noted. Money from communal *ngitilis* went toward improving housing, Duguma says.

Biodiversity flourished, too. *Ngitilis* collectively housed over 150 species of trees, shrubs and other plants. With habitat restored, people in the region

began to hear the cries of hyenas at night, a welcome return, Duguma says. At least 10 mammalian species came back, including antelope and rabbits, and 145 bird species were recorded within the *ngitilis*.

There's an enormous need to scale up this kind of community-driven success across Africa, where roughly 60 percent of agricultural lands are degraded, says Susan Chomba, who led the Regreening Africa initiative before becoming director of Vital Landscapes at the World Resources Institute in Nairobi. Regreening Africa, an ambitious 2017 initiative led by World Agroforestry, hopes to reverse land degradation across 1 million hectares of sub-Saharan Africa by 2022 to improve the lives of people in 500,000 households.

There are many drivers of land degradation, "but the underlying issue is poverty," Chomba says. If a woman can feed her children only by cutting down a tree to sell firewood, her choice is clear, Chomba says. To offer better options, Regreening Africa hopes to couple agroforestry and sustainable land use practices. The aim is to generate income for local residents while restoring the landscape.

Central to that goal is close collaboration with local people. Some farmers may want to restore water to a region that used to have streams, or people may want shea trees for making profitable shea butter, Chomba says. Tree-planting schemes that come in with preformed ideas of what a region needs, without engaging and listening to the local community, won't get far, she says.

And land use policies are central to resident buy-in, Chomba says. In Africa, "we are coming from a history of colonialization," she says. As a result, much of the land that's forested, or could be restored by farmers, is state owned. Because trees are often state property, it is difficult for locals to profit from the sales of fruits and other tree products.

"If I'm planting a tree that will take years to grow, and I'm not guaranteed ownership of that tree or land, what's my incentive for investing in it?" Chomba asks. "Restoration efforts must be coupled with ensuring land rights."

After decades of tree cutting, the landscape of Tanzania's Shinyanga region dried up (top). In the 1980s, a focus on creating reserves of plant life called *ngitilis* transformed the landscape (bottom).

The U.S. breadbasket

In the United States, thoughts of agriculture likely conjure images of Iowa's endless cornfields or massive hog farms. While industrialized monoculture is the norm among big players, small-scale farmers are more able to incorporate trees into their fields, or bring crops into the forests.

According to the U.S. Department of Agriculture's 2017 Census of Agriculture, of the approximately 2 million farms in the United States, only 1.5 percent report practicing some form of agroforestry. This percentage is likely an underestimate, but experts say it reveals how much room there is to grow.

Agroforestry practices vary across the United States. In the Midwest, trees serve as windbreaks for crops and line creeks to minimize fertilizer runoff. In cattle country, ranchers plant honey locust trees in their pastures to provide shade during the summer and nutrient-rich pods that feed animals. Forest farming, where nontimber crops such as wild mushrooms or ginseng are grown within a managed or wild forest, is becoming more popular across the eastern states.

Agroforestry is all about breaking down the wall between agricultural lands and woodlands and blending them together, says John Munsell,

FROM TOP: DR. OTSYINA; L.A. DUGUMA/WORLD AGROFORESTRY

a forest management researcher at Virginia Tech in Blacksburg. "It's a way of thinking creatively across a landscape," he says. Often, small-scale farmers are more game for trying.

Anna Plattner and Justin Wexler have had to get creative to support their farm in New York's Hudson Valley. The 38-hectare farm grows heirloom plants used by the Mohican and Munsee peoples indigenous to the region. The farm also incorporates traditional agroforestry methods, Wexler says. Rows of pawpaw and persimmon trees are staggered between native varieties of corn, beans and squash. The farm also grows more obscure foods, including hopniss, a legume that was a staple for some Native American tribes before Europeans arrived.

Wexler says he hopes that focusing on foods of Indigenous peoples can help others learn about the history and culture of the area. Demand for these unfamiliar crops isn't high, so in addition to selling to wholesalers and restaurants, this year, Plattner and Wexler debuted monthly "wild harvest boxes" — a sort of local Blue Apron for native produce. The boxes come stuffed with snippets of history about the foods and recipe ideas. "Every plant has its own story to tell," Plattner says.

Small farms may be more willing to embrace agroforestry, but to meet the looming challenges of climate change and biodiversity loss, large farms need to as well.

In the United States, "there is huge potential to scale up agroforestry," says agroecologist Sarah Lovell, director of the Center for Agroforestry at the University of Missouri in Columbia.

For Lovell, step one involves identifying marginal areas on farms where trees could be planted with minimal disruption to the status quo, such as along creeks. Putting trees around waterways can reduce flooding and erosion, improve water quality and house wildlife, Lovell says. In the "true breadbasket of the Midwest," she estimates, only 2 to 5 percent of such areas are currently making use of trees.

Eventually, she says she would like to see a drastic scaling up of alley cropping, with lines of fruit or nut trees fully integrated into fields. The need to move fruit and nut production east, away from increasingly drought-stricken California, may provide an extra push for bringing more trees onto monoculture farms, Lovell says.

But corn and soybean fields dominate much of U.S. agricultural land. These lucrative crops serve as raw materials for everything from biodiesel to high fructose corn syrup. To convince farmers to replace some of those crops with trees, the fruits of those trees will have to become more mainstream. The Savanna Institute, an agroforestry nonprofit in Madison, Wis., is focused on expanding the market for chestnuts and hazelnuts.

Anna Plattner and Justin Wexler practice forest farming, growing shiitake mushrooms on logs in wooded areas and collecting wild golden oyster mushrooms (shown) to sell at farmers markets and to local restaurants.

COURTESY OF WILD HUDSON VALLEY

"We call them corn and soybean on trees," says Savanna Institute ecologist Kevin Wolz. Chestnuts are about 90 percent starch, like corn; hazelnuts are 75 percent oil and protein, like soybeans, Wolz says. Researchers at the institute are working out just how these tree products could replace corn and soy as raw materials in production pipelines, with rows of nut trees breaking up monoculture fields. "We think these could be the next commodity crops that the Midwest can produce," Wolz says.

Whether we'll be drinking soda sweetened with chestnut syrup anytime soon remains to be seen. But to transform agriculture from a climate change problem to a solution, Wolz says such bold and imaginative thinking is essential.

Agroforestry isn't a silver bullet for addressing climate change, the biodiversity crisis or food insecurity, Wolz says. But when applied with place and people in mind, he says it can be a Swiss Army knife. ■

Explore more

- Lalisa Duguma *et al.* "Shinyanga: blending old and new agroforestry to integrate development, climate change mitigation and adaptation in Tanzania." World Agroforestry. 2019. bit.ly/WA-Agroforestry

Finding the Mother Tree
Suzanne Simard
KNOPF, $28.95

BOOKSHELF

A forest social network

Opening Suzanne Simard's new book, *Finding the Mother Tree*, I expected to learn about the old growth forests of the Pacific Northwest. I had an inkling that Simard, a forest ecologist at the University of British Columbia in Vancouver, would walk through her painstaking research to convince logging companies and others that clear-cutting large parcels of land is too damaging for forests to recover. I didn't expect to be carried along on her very relatable journey through life.

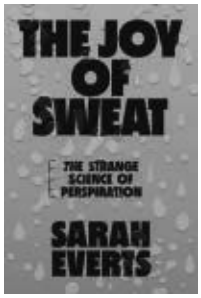
Simard was born in the Monashee Mountains of British Columbia in 1960. Her family of loggers selectively cut trees and dragged them out with horses, leaving plenty still standing. In her first stab at a career, she joined a commercial logging company that clear-cut with large machinery. Her job was to check on seedlings the firm had planted in those areas to restart the forest. The fledgling plants were often yellowed and failing. Simard's instincts told her those trees were missing the resources that exist within a diverse community of plants, so she set out to see if her hunch was right.

She learned how to do experiments, with close calls with grizzly bears and other mishaps along the way, eventually becoming a tenured professor. She and colleagues discovered that underground networks of fungi among tree roots shuttle carbon and nutrients from tree to tree. Simard seamlessly weaves details of her studies of these networks with her life's travails: sibling relationships and loss, struggles as a woman in a male-dominated field and her own recovery from a health crisis. Like many women who work outside the home, she felt torn between being with her young daughters and pursuing her professional passions.

Readers will feel for Simard as much as they worry for the forests that are quickly disappearing (see Page 24). Simard presents plenty of evidence and writes enthusiastically to build her analogy of the "mother trees" — the biggest, oldest trees in a forest that nurture those nearby. In her experiments, seedlings planted near a mother tree were much more likely to survive.

"Trees and plants have agency," she writes. "They cooperate, make decisions, learn and remember — qualities we normally ascribe to sentience, wisdom, intelligence."

Simard encourages logging companies to save the mother trees when harvesting to maintain the networks of information — the internet of the forest. Industry change has been slow, but she's optimistic: "Sometimes when it seems nothing will budge, there's a shift." — *Cori Vanchieri*



The Joy of Sweat
Sarah Everts
W.W. NORTON & CO., $26.95

BOOKSHELF

Be at peace with your perspiration

The telltale darkened patches under our arms before a presentation. The cold slide of a clammy handshake. Sweat reveals what we often want to hide: our nervousness, fears and exertions, all with the slight odor of what we last ate.

But maybe it's time to find "serenity instead of shame" in sweat, argues science journalist Sarah Everts. Through her delightful book, *The Joy of Sweat*, Everts delivers what she calls a "perspiration pep talk" that drips with science and history.

Everts' plunge into sweat is full of energy, and her open curiosity about our much-maligned bodily secretion leaks onto every page. Temperature regulation through sweat, she notes, is a trait few species can boast. Every drop tells the tale of our evolution — our ability to keep our cool has literally kept us alive and thriving.

The book offers plenty of fascinating facts: Traces of drugs and diseases appear in our perspiration. Tiny drops of sweat create the fingerprint smudges used to identify us. Sweat may even hold clues about the nutritional content of what we eat.

While sweat "keeps us honest," Everts writes, it also raises questions. For instance, how long until companies start mining the potential data dripping off people's foreheads? Forget the smell of stinky feet — we may soon have to worry about the privacy implications of sweating in public.

But Everts is never too serious. She gamely gets her armpits professionally sniffed, and she joins naked, sweating audiences for sauna theater. She even goes smell-dating, working up a sweat in a crowd so potential mates could sniff for love — or at least, attraction.

These stories amuse, but a more profound point lingers. People collectively spend billions of dollars each year deodorizing, wicking sweat away and pretending with all their might that it doesn't exist. *The Joy of Sweat* shows how this demand was created by deodorant and antiperspirant makers who sold sweat as a problem in the first place. The clear advertising spin will make readers reflect on how much of our hygiene habits are the result of manufactured humiliation.

By highlighting history, Everts shows that any perceived problems of sweat are most often cultural, not biological. Sweat simply is "a body trying its best to do its thing," she writes. And if we let that message seep into our minds (and out our armpits), we too can revel in the joy of sweat.
— *Bethany Brookshire*

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SOCIAL MEDIA

Roaring good rhyme

Contagious yawns may help lions synchronize their movements, **Jake Buehler** reported in "Yawning lions move in sync" (*SN: 5/8/21 & 5/22/21, p. 12*). On Twitter, reader **@starrylamp** shared an inspired rhyme: "Yawning in public / Is simply outrageous / Cuz everyone knows / That yawning's contagious!"

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When birds collide

*Citizen science and bird migration data could help prevent birds from colliding with wind turbines, **Jack J. Lee** reported in "How to keep birds safe as U.S. wind farms expand"* (SN: 5/8/21 & 5/22/21, p. 4). Reader **N. Adler** noted that the story mainly discussed large birds such as eagles and whooping cranes. "Are smaller birds also in danger from being killed by the turbines?" **Adler** asked.

Smaller birds are affected too, **Lee** says. In fact, a 2014 study in *PLOS ONE* estimated that songbirds make up about 60 percent of wind turbine–related bird fatalities in the United States and Canada. "This may be because songbirds are one of the most abundant bird groups in these countries," **Lee** says. "Raptors, a group of birds that includes eagles, seem to be particularly vulnerable to wind turbine collisions because of their flight behaviors, and their populations can be more at risk of decline due to low reproductive rates."

Mask up

*A microscopic look at the particle-filtering properties of different fabrics reveals the unseen, textured world of face masks, **Emiliano Rodríguez Mega** reported in "Texture matters for face mask protection"* (SN: 5/8/21 & 5/22/21, p. 5). Reader **Tim Baldwin** wanted to know how the size of the spaces between face mask fibers compares with that of the coronavirus that causes COVID-19.

Each coronavirus particle is about 100 nanometers across, molecular biology and senior writer **Tina Hesman Saey** says. Some scientists say an aerosol droplet must be at least 4.7 micrometers across to hold enough virus to be infectious. While there may be gaps between the fibers of cloth face masks larger than the droplets, a couple layers of material make it unlikely that those gaps will line up to let the droplets through, **Saey** says.

Smashing science

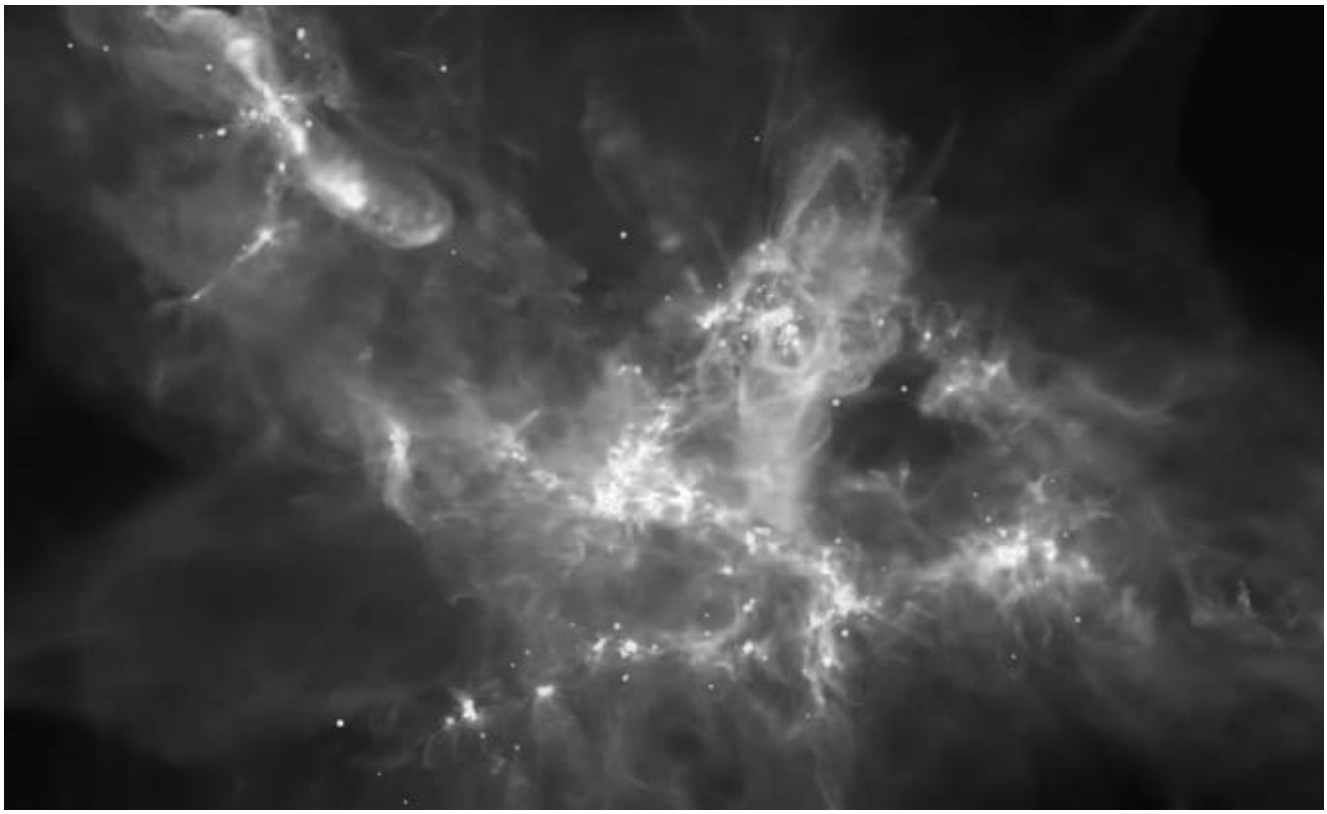
*Scientists in the lab observed a mysterious magnetic property of subatomic particles called muons that could upend the standard model of particle physics, **Emily Conover** reported in "Muons may signal new physics"* (SN: 5/8/21 & 5/22/21, p. 6). Reader **Jorge Ramos** wondered if muons exist in atoms in nature or if the particles are made only in the lab.

"Muons don't normally exist inside atoms," **Conover** says, "but they are present on Earth naturally." The particles form when cosmic rays from space crash into Earth's atmosphere, producing a shower of muons. Physicists can create muons artificially by smashing protons into a target material, she says. "This way the scientists can generate a beam of muons that they can study, instead of a diffuse shower."

Less is more

*People default to addition when solving puzzles and problems, even when subtraction makes more sense, **Sujata Gupta** reported in "Subtraction does not come naturally"* (SN: 5/8/21 & 5/22/21, p. 8). Reader **Robert Cox**, a tutor, and some of his students noticed that the study participants were based in the United States and wondered if this preference for addition applies to other cultures.

The researchers did a preliminary study among university students in Japan and Germany, **Gupta** says. That study's findings suggest that the tendency to add rather than subtract may be widespread. But more work is needed to understand why people default to addition, including how cultural factors such as social norms, industrialization and aesthetic preferences might influence that tendency, the researchers say.



A simulated peek into the birthplace of stars

The most realistic computer simulation of star formation yet offers stunning views of what the inside of a stellar nursery might look like.

In the Star Formation in Gaseous Environments simulation, or STARFORGE, a giant cloud of gas collapses into a nest of new stars. Unlike other simulations, which render only a small parcel of a larger gas cloud, STARFORGE simulates an entire star-forming factory. It's also the first simulation to account for all the phenomena thought to influence star formation, researchers report online May 17 in *Monthly Notices of the Royal Astronomical Society*.

"We sort of know the basic story of star formation ... but the devil is in the details," says Mike Grudić, an astrophysicist at Northwestern University in Evanston, Ill. Astronomers still don't fully understand, for instance, why stars have different masses. "If you really want to get the full picture," he says, "then you really have to just simulate the whole thing."

STARFORGE starts by simulating a blob of gas (one shown above) that can be tens to hundreds of light-years across and up to millions of times the mass of the sun. Turbulence creates dense pockets (white) that collapse to forge new stars. Those stars then launch powerful jets (left), give off radiation, shed stellar winds and explode in supernovas. (In these snapshots, orange gas has lots of variation in its motion; purple is more tranquil.) Eventually, these phenomena blow the last vestiges of the cloud away, leaving behind a hive of young stars. The whole process takes millions of years in the cosmos — or months of time on a supercomputer.

Using STARFORGE, Grudić and colleagues have confirmed that jets launched by new stars help regulate how much material a star amasses. In simulations without jets, typical stars were about 10 times the mass of the sun — way bigger than the actual average star. But with jets, Grudić says, "stellar masses start coming out more or less right on the dot for what they're observed to be." — *Maria Temming*

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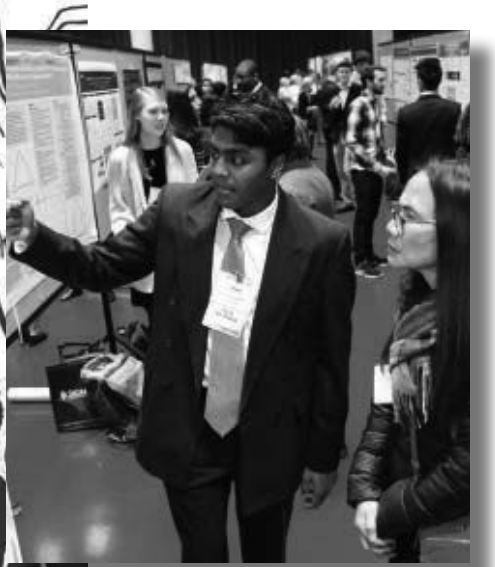

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