

Brain Death Defined | Catching a Comet's Birth

# ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ SEPTEMBER 12, 2020

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can influence food and drink



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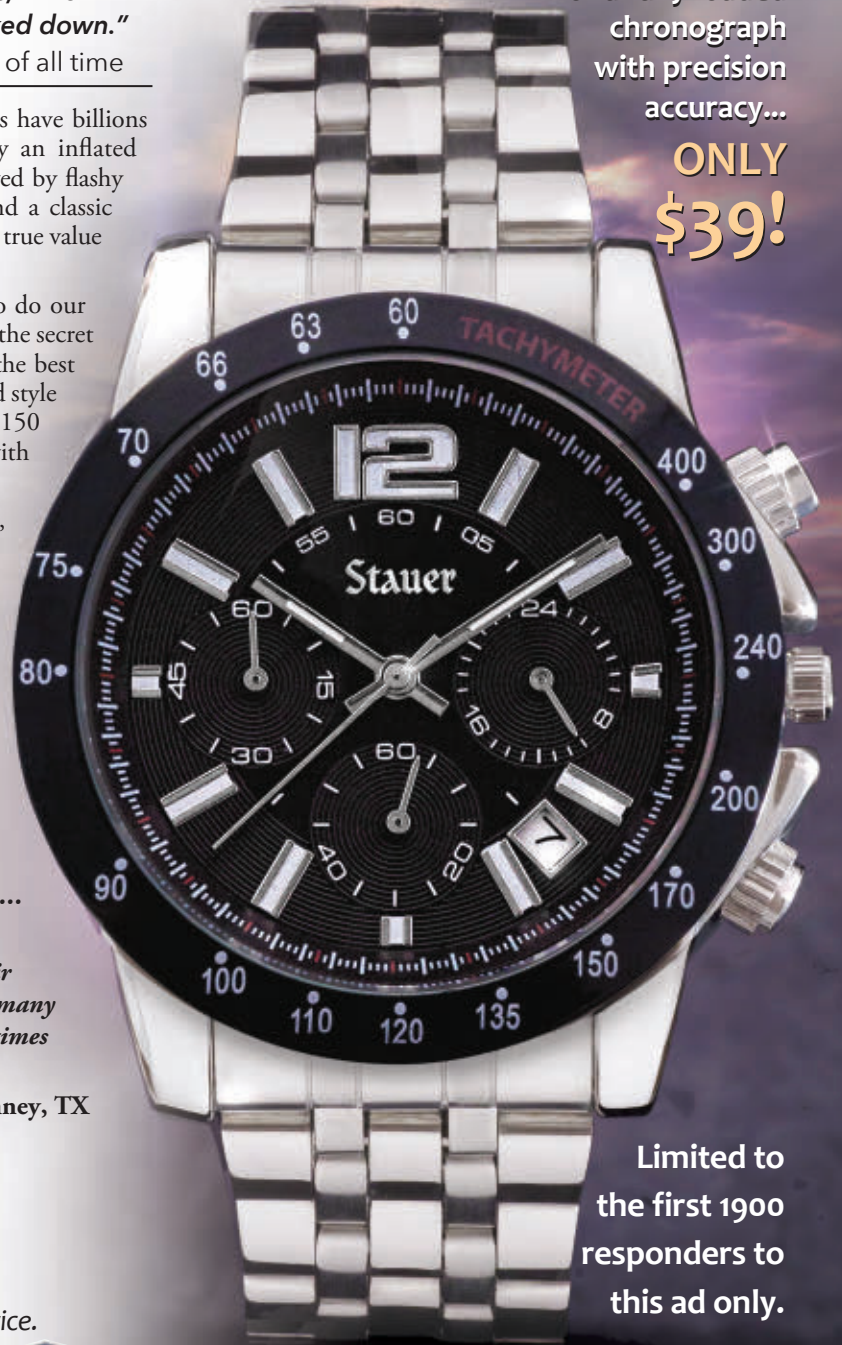
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**COVER** Soil, climate and microbes may shape the flavor of crops like wine grapes, shown growing in New Zealand. *nazar\_ab/iStock/Getty Images Plus*

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## Where do we draw the line between life and death?

You'd think that it would be simple to determine if someone is dead. But making the call can be fraught, especially when there are cultural, religious and legal definitions of death that conflict with the science.

The invention of ventilators and other advanced care has further complicated the definition of brain death, making it possible for a person without brain function to have a heartbeat and be breathing. "It's a strange thing to have to accept that a person who looks alive is actually brain-dead," *Science News* neuroscience writer Laura Sanders told me. "That relatively recent possibility opened the door for confusion."

In this issue, Sanders reports on a new international effort to define brain death (Page 8). Clinicians from around the world reviewed the existing data, which are slimmer than you might think, and then outlined a set of steps to take before declaring someone brain-dead. The guidelines are a big improvement, but the diagnoses can still be complicated, sometimes relying on inconclusive tests and steps that vary with the patient's age.

And if it's confusing now, get ready for even more challenges in the future. Advances in brain science and in technology may blur the definition of death further. And they may change life, too, in ways both good and bad. Scientists may develop new ways to treat diseases, but drugs and implants could also be used to control our thoughts and emotions, or even change who we are — the stuff of dystopian novels.

Sanders, who has a Ph.D. in molecular biology, is fascinated by the deep questions raised when science races ahead of society. In 2019, she covered the startling news that Yale researchers had restored cellular activity to pigs' brains hours after the animals had been killed at a slaughterhouse (*SN*: 5/11/19 & 5/25/19, p. 6). "This gets at one of the most fundamental questions we have: What it is to be alive," Sanders says. "As scientists get closer to understanding how the brain operates, they're going to be able to start clarifying those limits in totally new ways. And that, of course, will raise more questions."

Among them is whether people will agree to limits set by science and the law. When doctors declared Jahi McMath, a Black California teenager, brain-dead after a 2013 tonsillectomy, her parents challenged that decision. They drew support from religious and civil rights groups, and moved Jahi to New Jersey, which allows religious objections to the diagnosis. Jahi spent more than four years on a ventilator; the family's attorney said she died in June 2018 of liver failure.

In this issue we dive into another scientific advance that prompts big questions — genetically engineering mosquitoes to combat diseases. After a decade of contention, officials in the Florida Keys approved releasing GM mosquitoes to fly freely in the United States for the first time, life sciences writer Susan Milius reports (Page 6). The company that breeds the modified males says it addressed people's concerns about environmental impacts. Harder to address is skepticism about corporations and governments tinkering with nature.

We'll continue to explore these complex questions of how scientific advances impact our world. Stay tuned. — *Nancy Shute, Editor in Chief*

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Excerpt from the September 19, 1970 issue of *Science News*

50 YEARS AGO

## Amoebic killers

A fearsome [disease] has been recognized in recent years, produced by a one-cell organism.... Mercifully, human invasion is rare, for the invader, an amoeba, destroys the brain tissue and produces death in from four to seven days. Only 50 cases are known.... This free-living amoeba, *Naegleria gruberi*, is not confined to tropical countries.... Four deaths traced to *Naegleria* occurred in 1967–69 in Virginia.

**UPDATE:** The brain-eating amoeba, *Naegleria fowleri* — misidentified as its harmless cousin *N. gruberi* in *Science News* — causes a rare but deadly brain infection. Just four of 145 people infected with *N. fowleri* in the United States from 1962 to 2018 survived, reports the Centers for Disease Control and Prevention. The amoeba primarily infects people swimming in lakes and rivers, though several reported cases have been linked to contaminated tap water. Scientists are still trying to understand how the amoeba kills. “Brain-eating” may be a misnomer, recent research hints. Death could result from the immune system’s response to *N. fowleri* (*SN*: 8/22/15, p. 14).



SOAPBOX

## Hurricanes have names. Heat waves should too, some climate experts say

People in Paris cool off during a heat wave that seared Europe in 2019.

Hurricane Maria and Heat Wave Henrietta?

For decades, meteorologists have named hurricanes and ranked them according to severity. Naming and categorizing heat waves too could increase public awareness of these extreme weather events and their dangers, contends a newly formed group that includes public health and climate experts. Developing such a system is one of the first priorities of that international coalition, called the Extreme Heat Resilience Alliance.

Hurricanes get attention because they cause obvious physical damage, says climate scientist Jennifer Marlon of Yale University, who is not involved in the alliance. Heat waves, however, have less visible effects, since the primary damage is to human health.

From 1986 through 2019, heat waves have killed more people in the United States than any other weather-related disaster. There were 4,257 deaths as a result of heat, the National Weather Service reports, more than deaths from floods, tornadoes or hurricanes over the same period.

Climate change is amplifying the dangers of heat waves by increasing the likelihood of high-temperature events worldwide. Heat waves linked to climate change include the powerful event that scorched Europe during June 2019 and the sweltering heat in Siberia during the first half of this year (*SN*: 8/15/20, p. 13).

Populations that are vulnerable to health problems from high heat include people over 65 and those with chronic medical conditions. Historical racial discrimination also puts communities of color at disproportionately higher risk,

says alliance member Aaron Bernstein, a pediatrician at Boston Children’s Hospital and the interim director of Harvard’s Center for Climate, Health and the Global Environment. For instance, housing policies have concentrated these communities in urban areas lacking the green spaces that help neighborhoods cool down.



Aaron Bernstein belongs to a group seeking to categorize heat waves.

The naming and ranking process will involve defining what a heat wave is. No universal definition currently exists. The National Weather Service issues excessive heat warnings when the maximum heat index — which reflects how hot it feels by taking humidity into account — is forecast to exceed about 41° Celsius (105° Fahrenheit) for at least two days and nighttime air temperatures stay above roughly 24° C (75° F). The World Meteorological Organization and the World Health Organization describe heat waves as periods of excessively hot weather that cause health problems.

Without a universal definition, “we don’t have a common understanding of the threat we face,” Bernstein says. Categorizing heat waves could help local officials better address potential health problems as temperatures rise.

The alliance is in talks with the U.S. National Oceanic and Atmospheric Administration and other institutions to develop a standard naming and ranking practice. — *Jack J. Lee*

RETHINK

## Newfound cells in mice have versatile palates

Taste buds turn food from mere fuel into a memorable meal. Now researchers have discovered a group of supersensing cells in mice's taste buds that can detect four of the five flavors the buds recognize. Bitter, sweet, sour and umami — some of the cells can catch them all. Taste cells had been thought to detect just one or two flavors.

When Debarghya Dutta Banik, a neurophysiologist now at the Indiana University School of Medicine in Indianapolis, and colleagues turned off the sensing abilities of specific taste cells in mice, other cells still responded to flavors. Pulling out those cells and exposing them to several compounds revealed a group of cells that sense chemicals from across taste classes, the team reports August 13 in *PLOS Genetics*.

The team then monitored the brains of mice lacking a protein that multitasking cells use to relay information. Brains didn't get flavor messages from multitasking cells and missed some signals from specific taste cells. That suggests multitasking cells may work with specific taste cells to communicate. "The presence of these [newfound] cells completely disrupts how people think the taste bud works," says coauthor Kathryn Medler of the University at Buffalo in New York. — *Carolyn Wilke*

SCIENCE STATS

## Wild bees are moneymakers for some U.S. farms

U.S. cherries, watermelons and some other summertime favorites may depend on wild bees more than previously thought.

Many farms in the United States use managed honeybees to pollinate crops and increase production. Now an analysis of seven crops across North America shows that wild bees can increase the harvest on farms abuzz with managed honeybees. Wild volunteers add at least \$1.5 billion in total to production for six of the crops, researchers report in the July 29 *Proceedings of the Royal Society B*.

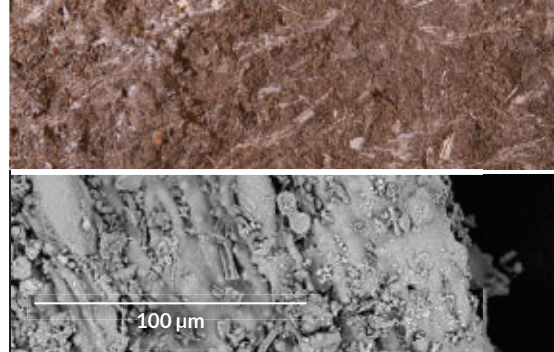
"The big surprise was that we found so many wild bees even in intense production areas where much of the produce in the USA is grown," says pollination ecologist Rachael Winfree of Rutgers University in New Brunswick, N.J. Winfree and colleagues spot-checked visits from wild and managed bees to flowers at 131 commercial farm fields across the United States and part of Canada. In a novel twist, the team checked for signs that there were too few managed bees to get the maximum production by depending on these bees alone. This information let researchers estimate to what extent native bees were filling in gaps.

Based on orchards in Michigan and Pennsylvania, some \$1.06 billion of apples depends on native pollinators, the researchers say. Watermelons get an estimated \$146 million benefit, and sweet cherries \$145 million. Native bees also dominate pumpkins and boost tart cherries and blueberries (a bumblebee visiting a blueberry flower is shown below). — *Susan Milius*

\$1.5  
billion

Minimum value from wild bee pollinators for six U.S. crops

FROM TOP: L. WADLEY, © FAYE BENJAMIN



THE -EST

## Early grass bedding went up in flames

People living in southern Africa around 200,000 years ago not only slept on grass bedding, but also occasionally burned it, apparently to keep from going buggy.

Remnants of the oldest known grass bedding (shown above, top), discovered in South Africa's Border Cave, lay on the ashes of previously burned bedding, say archaeologist Lyn Wadley of the University of the Witwatersrand in Johannesburg and colleagues. Ash spread beneath bound bunches of grass may have been used to repel crawling, biting insects, which cannot easily move through fine powder, the researchers report in the Aug. 14 *Science*. Wadley's team also found in the bedding bits of burned wood containing fragments of camphor leaves, an aromatic plant that is used as a bug repellent today.

Before this find, the oldest plant bedding — mainly consisting of sedge leaves, ash and aromatic plants — dated to around 77,000 years ago at South Africa's Sibudu rock-shelter.

At Border Cave, chemical and microscopic analyses of excavated sediment (above, bottom) showed that a series of beds had been assembled from grasses, such as guinea grass and red grass. Guinea grass currently grows at Border Cave's entrance. Bedding past its prime was likely burned in small fire pits, the researchers suspect. Remains of fire pits were found not far from Border Cave's former grass beds.

Hominids in southern Africa intentionally lit fires by around 1 million years ago (*SN*: 5/5/12, p. 18). But Border Cave provides the earliest and best evidence that ancient grass bedding was burned on purpose. — *Bruce Bower*

EARTH & ENVIRONMENT

## Florida Keys OKs GM mosquitoes

A much-debated public health tool is set to be tested in 2021

BY SUSAN MILIUS

After a decade of fits and starts, officials in the Florida Keys have voted to allow the first U.S. test of free-flying, genetically modified mosquitoes as a way to fight naturally occurring mosquitoes and the diseases they spread.

The decision came after about two hours of contentious testimony in a virtual public hearing on August 18. Many speakers railed against uncertainties in releasing genetically engineered organisms. In the end, worries about mosquito-borne diseases proved more compelling. On the day of the vote, in Monroe County, where the Keys are located, there were 47 locally acquired cases of dengue fever so far in 2020, the first surge in a decade.

The same mosquitoes known for spreading yellow fever also carry dengue, Zika and chikungunya. The species, *Aedes aegypti*, is especially hard to control among about 46 kinds of mosquitoes in the Keys. Florida Keys Mosquito Control District treatments kill only an estimated 30 to 50 percent of targeted *Ae. aegypti* mosquitoes, says Phil Goodman, chairman of the control district board.

“We can’t rely on chemistry to spray our way out of this,” Goodman, a chemist himself, said as the board conferred on what policy to set after hearing the public’s comments. Then 4–1, the board voted to go forward with a test of genetically modified males as pest control devices.

Sometime in 2021 workers will set out boxes of eggs of specially bred male mosquitoes in a stretch of Monroe County still to be chosen. The eggs, shipped from the biotech company Oxitec, based in Abingdon, England, will grow into



In 2021, the Florida Keys plans to test genetically modified mosquitoes in the wild as a way to combat the disease-spreading *Aedes aegypti* (shown).

normal-looking males. Like other males, they drink nectar, not blood.

Planners hope these Oxitec males will charm females into mating. A bit of sabotage genetics from the males will kill any resulting female offspring, and over time that should shrink the swarms. Sons that inherit the no-daughter genes will further shrink the next generations.

Oxitec has supplied some billion sabotage males for release elsewhere around the world, such as in Brazil. The notion of releasing sterile males of a pest to romance the population down is at least 80 years old (*SN*: 7/14/12, p. 22). For decades, that meant sterilizing males by exposing them to radiation and then releasing them. But mosquitoes were too delicate for the radiation techniques of the time. When scientists figured out an efficient way to tweak a fruit fly’s DNA, reported in 1982, hopes rose for genetically sterilizing male pest insects.

Oxitec’s batch for Florida will not be the first GM insects to fly free in the United States. That distinction goes to modified pink bollworm moths, released in 2006, for an eradication program to wipe out this cotton pest in the Southwest. A genetic tweak supplied a marker that would ID irradiated insects but didn’t change fertility genes. The first GM self-limiting insects to fly free in the United States were crop pest diamondback moths in a 2017 New York test.

The application to test GM mosquitoes in Florida got over 5,000 individual comments, plus a petition against the project that drew over 25,000 signatures.

Some common concerns involve stray antibiotic traces in the outdoors under-

cutting the controls, says public health entomologist Kevin Gorman of Oxitec. In breeding colonies, Oxitec adds the antibiotic tetracycline to the water, which suppresses the female-killing gene and lets females live to lay eggs for pest control. In the outdoor world, however, plant saucers or birdbaths where mosquitoes lay eggs are not likely to be drugged. The genetic daughter-killer switches on and starts destroying female mosquitoes.

The outdoors, however, isn’t free of tetracycline. To reduce the risk of accidental traces letting females live to biting age, the U.S. Environmental Protection Agency has required that Keys’ test sites be at least 500 meters away from sewage places, where antibiotics can arrive in waste, and from citrus orchards, which get their own antibiotic treatments.

Other questions concern the Oxitec breeding stock’s natural genes, not the engineered extras, mixing into the wild populations. Oxitec can say, at least, that this spread should not make the wild ones more difficult to kill than they already are. The latest Oxitec mosquitoes are susceptible, for example, to pyrethroid pesticides, which many Keys *Ae. aegypti* mosquitoes no longer are, Gorman says.

More general objections may have more to do with suspicions of government and businesses than with biology. Some unease, too, may come from human reaction to risk and control, says public health entomologist Natasha Agramonte of the University of Florida in Gainesville. Car crashes injure several million Americans a year, but driving lets people feel they’re in control. Watching mosquitoes being released? Not so much. ■



# Art hints at universal facial expressions

Ancient sculptures provide a cross-cultural look at emotions

BY BRUCE BOWER

Grimaces, scowls and dotting gazes of ancient human sculptures indicate that there are universal facial expressions that signal the same emotions across cultures, researchers argue.

Faces depicted in sculptures crafted between 3,500 and 600 years ago in Mexico and Central America convey five varieties of emotion to Westerners today, say computational neuroscientist Alan Cowen and psychologist Dacher Keltner of the University of California, Berkeley. Present-day folks, and likely members of ancient American societies as well, link each of these emotional expressions to particular social situations, the scientists report August 19 in *Science Advances*.

As participants in the study predicted just by looking at the sculptures' faces, pain expressions characterized sculptures of people being tortured, expressions combining determination and strain accompanied heavy lifting, angry faces occurred in combat, elated expressions appeared in people being held or embraced, and sad faces typified individuals in defeat.

That link between ancient and modern groups "provides strong support for universality and genetic origins of these [particular] emotion expressions," says psychologist Jessica Tracy of the University of British Columbia in Vancouver.

Cowen and Keltner regard their findings as a preliminary glimpse of how people who lived long ago, and who had no exposure to any modern culture, expressed certain emotions with their faces as Westerners now do. Researchers have argued for decades about whether certain facial expressions have evolved to express specific emotions, such as happiness, anger and disgust, regardless of one's culture. Previous comparisons of facial expressions across different modern societies have been complicated by the fact that people everywhere,

including hunter-gatherers, have to some extent encountered Westerners and been influenced by their practices. By looking deep into the past, the new study gets around that problem, the researchers say.

The investigators first identified 63 ancient sculptures, mostly from Mexico and Central America, from museum collections portraying people in eight situations: being held captive, being tortured, carrying a heavy object, embracing someone, holding a baby, preparing to fight, playing a ball game and playing music.

A total of 325 English-speaking participants, averaging nearly 36 years old, viewed images of each sculpture's face without being able to see the rest of the sculpture or discern its context. Volunteers rated either the extent to which faces portrayed 30 emotions, such as awe and anger, or the extent to which faces displayed 13 broader emotional states, such as pleasantness and alertness.

Another 114 participants rated the extent to which someone in each of the eight depicted situations — described to the participants in written accounts — would express the 30 emotions or 13 emotional states.

Sculptures' facial expressions generally aligned with what participants expected to see in each situation. On average, for example, expressions of pain and distress clustered among sculpted individuals shown being tortured, in line with what Westerners predicted would occur.

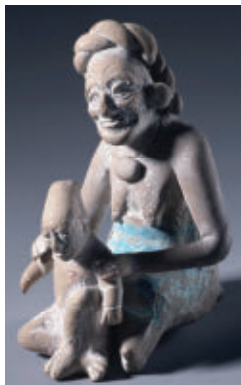
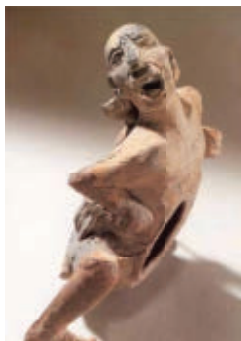
These findings suggest that facial expressions have evolved to convey a richer variety of emotions than

scientists have often assumed, Cowen says. For instance, a well-known system that categorizes seven basic emotions communicated by the same facial expressions in all cultures does not include expressions of pain and of the combination of determination and strain.

Cowen and Keltner deserve credit for taking a novel approach to studying facial expressions, but the results won't quell debate over whether certain expressions communicate the same meaning across cultures, says psychologist Deborah Roberson of the University of Essex in England. English speakers today hold consistent assumptions about how facial expressions should be deployed, as the study shows, Roberson says. But ancient cultures likely put distinctive spins on nonverbal emotional communication that scientists today may never be able to recognize, she contends.

Yale University psychologist Maria Gendron agrees. Even today, emotional meanings of faces may not translate across cultures, she says. For instance, Trobrianders of Papua New Guinea perceive anger and threat in the same wide-eyed, gasping faces that Westerners view as expressions of fear.

People living in small, relatively isolated communities, such as Himba farmers and herders in southern Africa, often rank facial emotions differently than Westerners do if asked to describe on their own what a facial expression shows, Roberson says. In such traditional societies, everybody knows each other well, so there is no need to assume that facial expressions reflect particular emotional states, she argues. "If someone is mean and grouchy most of the time, you are likely to be wary of them even when they're smiling." ■



In a study of emotional expressions, people recognized pain (top) and elation (bottom) on the faces of these more than 1,000-year-old sculptures.

## HUMANS &amp; SOCIETY

# Soccer helped ease interfaith tensions

A social intervention in Iraq showed benefits and limitations

BY SUJATA GUPTA

Bringing rival groups together to reduce prejudices is not a new idea. But can positive contact help ethnic groups reconcile after extreme violence? A social scientist tested that idea by putting Christians and Muslims in Iraq on the same soccer teams. The resulting camaraderie among players bridged those communities — but only to a point.

Relations between Muslims and Christians disintegrated in northern Iraq after the Islamic State captured Mosul and surrounding areas in 2014. Thou-

sands of Christians were forced to flee the region, returning years later to live uneasily alongside Muslims who many saw as complicit in the attacks. Political scientist Salma Mousa of Stanford University, a soccer fan who grew up in the Middle East and Canada, wondered if the sport could bring the groups together.

Players did make some small behavioral changes. For instance, at the end of the two-month league, almost 76 percent of Christian players on mixed teams agreed to register for mixed teams the following season, compared with 63 percent

of players on all-Christian teams, Mousa reports in the Aug. 14 *Science*. Six months later, almost 64 percent of Christian players from mixed teams were training with Muslim players at least once a week, compared with about 15 percent of players from the all-Christian teams.

But Mousa didn't find that sort of interethnic camaraderie off the field. For instance, even after being given an \$8 voucher to a Muslim-owned restaurant, Christian players from mixed teams weren't any more likely than players from segregated teams to go.

"I was hoping... contact would solve everything," Mousa says. "At first I was disappointed, but then I actually started to think it is a win to even have this positive dent" in improving relations.

Mousa's work hinges on the "contact hypothesis," the idea that positive interactions among rival group members can reduce prejudices. That idea underlies many global peacekeeping efforts. The experiment is the first study they know of showing that such contact can actually shift real-world behavior, behavioral psychologists Elizabeth Levy Paluck and Chelsey Clark of Princeton University write in a commentary in *Science*.

Recreational adult soccer teams in northern Iraq are segregated by religion. So Mousa invited Christian teams



Christian children displaced by the Islamic State are shown playing soccer in Iraq in 2017. Because of the sport's popularity, a researcher tested whether soccer could improve relations between Iraq's Christians and Muslims.

## BODY &amp; BRAIN

# Doctors define brain death

New guidance could ease debates over when life ends

BY LAURA SANDERS

When your brain stops working — completely and irreversibly — you're dead. But drawing the line between life and brain death isn't always easy. A report attempts to clarify that distinction, perhaps helping to ease the anguish of family members with a loved one whose brain has died but whose heart still beats.

There has been a lot of variation in how people define brain death, says Gene

Sung, a neurocritical care physician at the University of Southern California. "Showing that there is some worldwide consensus, understanding and agreement at this time will hopefully help minimize misunderstanding of what brain death is."

As part of the World Brain Death Project, Sung and other clinicians from around the world reviewed the existing research on brain death (which was slim) and used their clinical expertise to write recommendations on how to identify brain death, published August 3 in *JAMA*.

The minimum requirement for determining brain death is "a good, thorough clinical examination," Sung says. Before that exam, doctors ought to verify that a person has experienced a neurological injury or condition that could cause

brain death. Next, clinicians should look for other explanations, conditions that could mimic brain death but are reversible. Cooling the body, a procedure for treating heart attacks, can cause brain function to temporarily disappear. So can certain drugs, alcohol and other toxins.

Doctors need to test for physical responses that require a functioning brain: eye movement, pain responses and gag responses, among others. Physicians also should see whether a person attempts to breathe independently, a life-sustaining process that relies on the brain stem. If none of these signs are present, a person could be considered brain-dead. Extra tests, such as those that look for blood flow or electrical activity in the brain, may provide useful information,

in two cities to participate in her experiment, recruiting a few dozen teams. Teams received either three or four new Christian or Muslim players to play alongside nine Christian players already on the team, creating a mix of interfaith and all-Christian teams.

Mousa observed camaraderie among players on mixed teams. On one team, for instance, members pooled money to defray the cost of taxis for Muslim players traveling across town to practice. But when Mousa surveyed Christian players to see if their attitudes toward Muslims in general had shifted, she saw little to no change. For instance, Christians on mixed teams were no more likely than those on all-Christian teams to feel comfortable having Muslims as neighbors. Mousa likewise saw no shift in attitudes among the Muslim players.

Mousa's project adds to evidence suggesting, counterintuitively, that shifting people's behavior toward rival groups may be easier than shifting their attitudes, says political scientist Michael Gilligan of New York University. Arguably, changing how rivals act toward one another matters more anyway, he says. "It gives you hope that if this becomes a ramped-up program that is done throughout these areas, they may actually have a bigger impact." ■

but their interpretation isn't always straightforward, the authors caution.

Identifying brain death in adults should include at least one clinical exam; children should receive at least two. "Children can recover from a lot of different things differently from adults," Sung says. "We want to really make sure they have had a devastating injury."

Clarity from medical professionals is long overdue, says Paul Graham Fisher, a pediatric neurologist at Stanford University. But that's only a first step. Complex cultural, religious and even legal forces thwart a simple and universally accepted definition of brain death, he says. "You're still going to have people, on an individual level or a societal level, who may not buy in." ■

Woolly rhinos (illustrated) went extinct because climate change transformed arctic habitats, researchers contend.



#### LIFE & EVOLUTION

## Ice Age die-off blamed on climate shift

### Ancient DNA may exonerate humans in woolly rhino extinction

BY BRUCE BOWER

Rather than getting wiped out by Ice Age hunters, woolly rhinos charged to extinction when the climate turned warm and wet, a study of ancient DNA suggests.

Numbers of breeding woolly rhinos in northeastern Siberia stayed relatively constant from nearly 30,000 years ago until at least about 18,500 years ago, long after people first reached the region, scientists report online August 13 in *Current Biology*. But by around 14,000 years ago, woolly rhinos vanished.

A shift to warm, rainy conditions, which occurred between roughly 14,600 and 12,800 years ago, "likely played a large role in the rapid decline of this cold-adapted species," says Edana Lord, an evolutionary geneticist at the Centre for Palaeogenetics in Stockholm. During that period, open expanses featuring vegetation that woolly rhinos (*Coelodonta antiquitatis*) liked to eat were replaced by forests and shrub-dominated tundra. Hunters could have added to the rhinos' woes, but the main extinction distinction goes to climate change, Lord contends.

Researchers have argued for decades about whether climate change or humans had a larger effect on extinctions of large animals, such as woolly rhinos and mammoths, as the Ice Age approached its end around 11,700 years ago.

Lord's group extracted a complete set of nuclear DNA from a roughly

18,530-year-old woolly rhino bone. The team compared genetic variants between matching chromosomes to identify regions that were likely more ancestral than others, allowing the researchers to reconstruct changes in past breeding populations. Woolly rhino breeding numbers increased gradually starting around 1 million years ago and, by about 152,000 years ago, reached a peak of some 21,000 animals, the team estimates.

Humans entered northeastern Siberia by about 31,600 years ago. It's not known when people first inhabited Siberia year-round, but the new analysis shows that woolly rhinos continued to thrive long after humans likely knew of the animals' existence. From about 29,700 to 18,530 years ago, when the animal that yielded the DNA was alive, breeding woolly rhinos numbered about 10,600, the team reports. Nuclear DNA from woolly rhinos that lived between around 18,000 and 14,000 years ago will be needed to determine when in that brief window the population of these animals plummeted.

Few examples of ancient DNA have been gleaned from any large Ice Age animals that died out, including woolly rhinos, says Pontus Skoglund, an evolutionary geneticist at the Francis Crick Institute in London. He agrees that "there is no evidence so far of human hunting being a deciding factor in woolly rhino extinction." ■

## BODY &amp; BRAIN

# Cat drugs could combat COVID-19

Preliminary studies suggest new treatments to test in humans

BY ERIN GARCIA DE JESUS

In the rush to find COVID-19 treatments, researchers are exploring myriad possibilities, even drugs intended for cats.

Preliminary work suggests that two experimental drugs that can cure an often lethal coronavirus infection in cats, called feline infectious peritonitis, might help people infected with SARS-CoV-2, the coronavirus behind the current pandemic.

In lab experiments, one of the drugs, called GC376, disabled an enzyme that SARS-CoV-2 uses to replicate. The other drug, GS-441524, is an antiviral cousin of remdesivir, the first drug found to speed recovery from COVID-19 in clinical trials.

“Both drugs have been highly effective in curing cats with feline infectious peritonitis, and usually without any other form of treatment,” says veterinarian Niels Pedersen of the University of California, Davis. Neither drug, however, has yet been approved by the U.S. Food and Drug Administration for use in cats, much less in humans.

While most animals infected with feline coronavirus don’t show symptoms, some cats can develop feline infectious peritonitis if the virus mutates to infect a specific type of immune cell. When that happens, the virus spreads throughout the body, sparking a deadly inflammatory reaction that can cause paralysis, or cause fluid to accumulate in the lungs.

In that way, the cat coronavirus is similar to SARS-CoV-2. Both severe COVID-19 in people and feline infectious peritonitis cases are driven by a dysfunctional inflammatory immune response, says Julie Levy, a veterinarian at the University of Florida in Gainesville.

GC376 works by preventing the enzyme M protease, found in a number of different coronaviruses, from chopping up long strings of viral proteins. The process of chopping up protein strings into smaller pieces plays a key role in the replication process for viruses like SARS-CoV-2 that have RNA as their genetic material (*SN*: 3/28/20, p. 20). Hindering the protease’s ability to cut

can halt viral replication.

In a 2016 study, six of eight cats recovered from infection with the deadly form of the feline coronavirus after treatment with the drug, Pedersen and colleagues reported in *PLOS Pathogens*. The two cats that died may have suffered from complications of a separate drug given to alleviate the disease, the team noted.

The researchers also reported that in a test tube, GC376 inhibited the proteases from two coronaviruses that caused severe outbreaks in people: the SARS and MERS viruses.

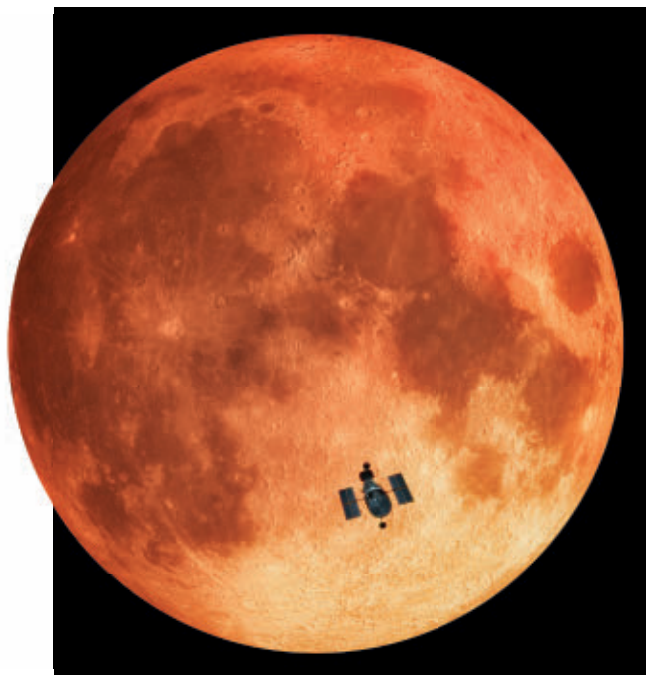
In the new experiments, researchers including chemist Jun Wang of the University of Arizona in Tucson have found that, in a test tube, GC376 can also stop SARS-CoV-2’s M protease from working. Wang, whose group reported those results in the August *Cell Research*, says his team is now testing the compound in mice. And in results presented August 4 at the virtual American Crystallographic Association meeting, biochemist Joanne Lemieux and colleagues revealed that GC376 not only inhibits the SARS-CoV-2 enzyme in a test tube, but can also hinder viral replication in lab-grown monkey cells.

Based on those findings — and the

## ATOM &amp; COSMOS

## Earth from an alien’s perspective

To practice searching for extraterrestrial life, researchers have run a dress rehearsal with the one world they know to be habitable: Earth. While Earth was between the sun and moon for a lunar eclipse in January 2019, the Hubble Space Telescope (illustrated against the backdrop of the moon) observed how ozone in Earth’s atmosphere blocked certain wavelengths of sunlight from reaching the moon. That observing setup mimicked the way astronomers plan to probe the atmospheres of Earthlike exoplanets as they pass in front of their stars, filtering out some starlight. The observations revealed prominent dips in particular wavelengths of ultraviolet sunlight that had been absorbed by the ozone, researchers report in the September *Astronomical Journal*. The data help confirm that chemicals in Earth’s atmosphere filter light as expected, based on an understanding of atmospheric chemistry. That finding gives astronomers more confidence that they will be able to recognize potentially habitable exoplanets. — *Maria Temming*



M. KORNMESSER/HUBBLE/ESA

fact that the drug is safe and effective in cats – the company that makes GC376, Anivive Lifesciences, based in Long Beach, Calif., is now working to move forward with clinical trials in people, says Lemieux, of the University of Alberta in Edmonton, Canada.

“The fact that this drug has already been developed and shown to be successful in treating feline infectious peritonitis, it really bodes well,” Lemieux says.

The other cat drug, GS-441524, has a similar chemical structure to remdesivir, though remdesivir has an additional part that better helps the drug get into cells. Both remdesivir and GS-441524, developed by Gilead Sciences, based in Foster City, Calif., mimic a building block of RNA. As the virus replicates, it incorporates the copy-cat building block into its RNA, which prevents viral enzymes from adding more building blocks, stopping replication.

Understanding the connections between animal and human health can help tackle new viruses.

In 2018 in *Veterinary Microbiology*, Pedersen and colleagues reported that GS-441524 is an effective treatment for feline infectious peritonitis. The drug not only inhibited viral replication in lab-grown cells, but also successfully treated 10 of 10 infected cats that had severe disease. In a 2019 study in the *Journal of Feline Medicine and Surgery*, 25 of 26 cats treated with the drug for at least 12 weeks survived.

There are hints that GS-441524 might also help people with COVID-19. A study in the July 21 *Cell Reports* found that the drug can inhibit SARS-CoV-2 replication in lab-grown monkey and human cells. Remdesivir was more potent in human lung cells, while GS-441524 was more potent in monkey cells.

Remdesivir was tested in people with Ebola during the 2014–2016 outbreak in West Africa and the 2018–2020 outbreak in Congo. While it wasn’t effective against

Ebola, knowing it wouldn’t harm patients allowed Gilead to leapfrog to testing it against SARS-CoV-2. The drug is now in COVID-19 clinical trials, some of which have shown that remdesivir can speed patient recovery. Gilead applied for FDA approval for remdesivir on August 10. The company has also begun preclinical studies to compare remdesivir and GS-441524, according to company spokesperson Chris Ridley.

While it remains to be seen if either GS-441524 or GC376 will work against SARS-CoV-2 in people, the drugs are an example of how understanding the connections between animal and human health can help tackle new viruses. “Partly because of feline infectious peritonitis research, a lot of veterinarians seemed to realize early in the course of the COVID-19 pandemic that remdesivir could be a promising candidate,” says E. Susan Amirian, a molecular epidemiologist at Rice University in Houston. “Parallels between human and veterinary medicine are fascinating.” ■


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When they team up in massive swarms, locusts, such as these desert locusts, are among the most destructive agricultural pests.

## LIFE &amp; EVOLUTION

## Chemical coaxes locusts to swarm

Pheromone finding could lead to new pest control measures

BY JONATHAN LAMBERT

Locusts are usually harmless loners. But together, they become plagues.

When conditions are right, solitary locusts congregate and transmogrify into their “gregarious” form, becoming a bigger, more aggressive eating machine. These groups can grow into ever-larger conglomerations, potentially hundreds of millions strong, that cross continents and destroy crops, as is happening this year in East Africa, which is experiencing its worst locust plague in decades.

Scientists have pinpointed a compound emitted by congregating locusts that might explain how individuals of one species overcome an innate aversion to socializing. The finding, described online August 12 in *Nature*, could inform new ways of controlling or preventing locust swarms.

“We don’t have great ways of baiting locusts. This [compound] has potential,” says Baldwin Torto, a chemical ecologist at the International Centre of Insect Physiology and Ecology in Nairobi, Kenya, who wasn’t involved in the work.

Scientists had already suspected that airborne chemicals released by locusts called aggregation pheromones could act as an olfactory beacon, summoning

other normally solitary locusts to a swarm and initiating the transformation to more gregarious behavior.

Entomologist Le Kang of the Chinese Academy of Sciences in Beijing and colleagues searched for aggregation pheromones by identifying compounds emitted disproportionately more by gregarious migratory locusts (*Locusta migratoria*). The team puffed six such scents into arenas along with control scents. One compound, 4-vinylanisole, or 4VA, proved alluring to locusts of all sexes and ages, including solitary and gregarious forms.

That appeal is crucial, Torto says, because it demonstrates that 4VA could function to both bring solitary locusts into the fold of the swarm, as well as maintain a swarm’s cohesiveness.

Solitary locusts start emitting 4VA once they gather in groups as small as four or five, Kang’s team found. As a group grows, 4VA concentration shoots up, potentially broadcasting a larger signal and contributing to the exponential growth of swarms.

By setting sticky traps baited with 4VA, Kang and colleagues confirmed that the pheromone can attract locusts in the real world. On both artificial turf and a natural breeding area of migratory locusts in China, 4VA traps attracted more locusts than control traps, though the effect was modest in the field and attractiveness was tested only at short range.

4VA may not be the whole story, Torto says. In chemical communication among insects, multiple compounds often work

together, which this study didn’t address. Torto says there’s a chance that the background odors of gregarious locusts might interact with 4VA to amplify the aggregation signal.

Still, traps laced with 4VA might concentrate locusts and make treatment with insecticides or pathogens much easier, Torto says, especially if 4VA attracts other species as well, like the desert locust. Currently, many regions manage outbreaks by dumping pesticides on swarms from aircraft, which can harm livestock and the environment.

This study also opens the door for other control measures that alter the biology of locusts themselves. Kang and colleagues identified the protein that detects 4VA, nestled on specific sensory hairs that extend from locust antennae. Using the gene-editing technology CRISPR/Cas9, the team disabled this 4VA detector. Genetically altered locusts were not attracted to 4VA.

A compound that blocks antennae from sensing 4VA could be sprayed on locusts to prevent swarming, the researchers suggest. Alternatively, locusts genetically engineered to lack the 4VA detector, and thus less likely to swarm, could also be introduced into populations as a control measure.

“Anything that leads to a potential new management technology, especially one that can decrease reliance on synthetic pesticides, is really exciting,” says Arianne Cease, a sustainability scientist at Arizona State University in Tempe. But such technologies are still a ways away and could have side effects that would need to be better understood, she says. Further, changing the genetic makeup of a species has ethical consequences that would need to be weighed by people who might be affected, such as farmers.

Cease is also skeptical that simply turning off a gene would effectively prevent swarms. Becoming part of a swarm involves a whole set of radical changes to behavior, metabolism and body size (*SN: 2/28/09, p. 12*). Tweaking one aspect of this transformation may not prevent it, she says. “I’d be surprised if there were just one smoking gun.” ■

# Animals go far to flee ocean heat waves

Some species may have to swim thousands of kilometers for relief

BY CAROLYN GRAMLING

When an intense heat wave strikes a patch of ocean, marine animals may have to swim thousands of kilometers to find cooler waters, researchers report in the Aug. 6 *Nature*.

Such displacement, whether among fish, whales or turtles, can hinder both conservation efforts and fishery operations. “To properly manage those species, we need to understand where they are,” says Michael Jacox, a physical oceanographer in Monterey, Calif., with the National Oceanographic and Atmospheric Administration.

Marine heat waves — defined as at least five consecutive days of unusually hot water for a given patch of ocean — have become increasingly common over the last century. Climate change has amped up the intensity of some of the most famous recent marine heat waves, such as the Pacific Ocean “Blob” from 2014 to 2016 (*SN: 1/20/18, p. 6*) and scorching waters in the Tasman Sea in 2017.

“We know that these marine heat waves are having lots of effects on the ecosystem,” Jacox says. For example, the sweltering waters can bleach corals and wreak havoc on kelp forests. But scientists are only beginning to study the

impacts on mobile species such as fish (*SN: 2/15/20, p. 11*).

“We have seen species appearing far north of where we expect them,” Jacox says. In 2015, the Blob drove hammerhead sharks — which normally stay close to Baja California in Mexico — at least hundreds of kilometers north to the waters off Southern California.

To see how far a mobile ocean dweller would need to flee to escape the heat, Jacox and colleagues compared ocean temperatures around the globe. The team examined temperatures from 1982 to 2019 and identified marine heat waves, where water temperatures for a region lingered in the highest 10 percent ever recorded for that place and that time of year. Then the researchers calculated “thermal displacement,” how far a swimmer in an area with a heat wave would have had to go to find water temperatures that were typical for that time of year.

In higher-latitude regions, such as the Tasman Sea between Australia and New Zealand, relief tended to be much closer, within hundreds of kilometers of the overheated area, the researchers found. So while ocean heat waves in that region might spell doom for firmly rooted corals and kelp, mobile species might fare

better. “We were surprised that the displacements were so small,” Jacox says.

But in the tropics, where ocean temperatures are more uniform, species may have had to travel thousands of kilometers to escape the heat.

Projecting how species might move around in the future due to marine heat waves gets increasingly complicated, the researchers found. That’s because over the next few decades, climate change is expected to cause not just an increase in frequency and intensity of marine heat waves, but also warming of all of Earth’s ocean waters. And the rate of warming will vary from place to place. As a result, future thermal displacement could increase in some parts of the ocean relative to today, and decrease in others, marine ecologist Mark Payne of the Technical University of Denmark in Kongens Lyngby writes in a commentary in the same issue of *Nature*.


That complexity highlights the task ahead for researchers trying to predict changes across ocean ecosystems, says Lewis Barnett, a Seattle-based NOAA fish biologist who was not involved in the study. The new work provides important context for data being collected on fish stocks. For example, surveys of the Gulf of Alaska in 2017 noted a large decline in the abundance of valuable Pacific cod, now known to be linked to the Blob heat wave, which had ended the year before.

But there’s a lot more work to be done, Barnett says. The study focuses on surface temperatures, but conditions and dynamics are different in the deep ocean, he notes. Some species, too, move more easily between water depths than others. And heat tolerance varies from species to species. Biologists are racing to understand these differences, and how hot waters can affect the life cycles and distributions of many species.

The effects of marine heat waves might be ephemeral compared with the impacts of long-term climate change. But these extreme events offer a peek into the future, says marine ecologist Malin Pinsky of Rutgers University in New Brunswick, N.J. “We can use these heat waves as lessons for how we’ll need to adapt.” ■



In 2015, hammerhead sharks, normally found near Baja California, Mexico, were spotted hundreds of kilometers farther north during a marine heat wave.



A centaur is a space rock that could someday transform into a brilliant comet, like the one shown in this artist's illustration.

ATOM &amp; COSMOS

## Scientists spot a comet in the making

A space rock known as a centaur may grow a tail by 2063

BY LISA GROSSMAN

Like the mythical half-human, half-horse creatures, centaurs in the solar system are hybrids between asteroids and comets. Now, astronomers have caught one morphing from one type to the other, possibly offering an unprecedented chance to watch a comet form in real time.

“We have an opportunity here to see the birth of a comet as it starts to become active,” says planetary scientist Kat Volk of the University of Arizona in Tucson.

The object, called P/2019 LD2, was discovered in May by the ATLAS telescope in Hawaii. The orbit suggests that it’s a centaur, a class of rocky and icy objects with unstable orbits. Because of that mixed composition and potential to move around the solar system, astronomers have long suspected that centaurs are a missing link between small icy bodies in the Kuiper Belt beyond Neptune and comets that regularly visit the inner solar system (*SN*: 11/19/94, p. 334).

These “short-period” comets, which are thought to originate from icy objects in the Kuiper Belt, orbit the sun once every few decades or so and repeatedly light up Earth’s skies over human life spans. (Comets that visit the inner solar system only once every few thousand years, like Hale-Bopp, probably originate even farther out, in the Oort cloud.)

All previously found short-period comets were spotted only after they had become comets. But LD2 came in from the Kuiper Belt recently and will become a comet in as little as 43 years, Volk and

colleagues report August 10 at arXiv.org.

In 2019, Volk and colleagues showed that there’s a region of space just beyond Jupiter that they call the “Gateway.” In this area, small planetary objects hang out while warming up and transitioning from outer solar system ice balls to inner solar system comets with their long tails.

After hearing about LD2, the team simulated thousands of possible trajectories to see where LD2 had been and where it is going. LD2 probably flew near Jupiter around 1850 and entered its current orbit past Jupiter after a close encounter with the planet in 2017. LD2 will move in toward the sun in 2063, where heat from the sun will probably sublimate LD2’s volatile elements, creating a bright cometary tail, the researchers say.

The fact that LD2 will be a newcomer to the inner solar system suggests it’s made of relatively pristine material that has been in the back of the solar system’s freezer for billions of years. So studying LD2 may reveal what our solar system’s first planets were made of.

But studying just one transition object is not enough to open a solar system time capsule, says Henry Hsieh, a Honolulu-based astronomer with the Planetary Science Institute. “What we really need to do is study many of these,” he says, “and figure out whether this object is an outlier or whether we see a consistent picture.” Future sky surveys, like the ones planned using the future Vera C. Rubin Observatory, should discover more balls of ice shifting into comets. ■

ATOM &amp; COSMOS

## Positronium result baffles physicists

Energy level measurement eludes explanation for now

BY EMILY CONOVER

Positronium is positively puzzling.

A new measurement of the exotic “atom” — consisting of an electron and its antiparticle, a positron — disagrees with theoretical calculations, scientists report in the Aug. 14 *Physical Review Letters*. And physicists are at a loss to explain it.

A flaw in either the calculations or the experiment seems unlikely, researchers say. And new phenomena, such as undiscovered particles, also don’t provide an easy answer, adds Jesús Pérez Ríos, a theoretical physicist at the Fritz Haber Institute of the Max Planck Society in Berlin. “Right now, the best I can tell you is, we don’t know,” says Pérez Ríos, who was not involved with the new research.

Positronium is composed of an electron, with a negative charge, circling in orbit with a positron, with a positive charge — making what’s effectively an atom without a nucleus (*SN*: 9/15/07, p. 163). With just two particles and free from the complexities of a nucleus, positronium is appealingly simple. Its simplicity means it can be used to precisely test the theory of quantum electrodynamics, which explains how electrically charged particles interact.

A team of physicists from University College London measured the separation between two specific energy levels of positronium, what’s known as its fine structure. The team formed positronium by colliding a beam of positrons with a target, where they met electrons. After manipulating the positronium atoms with a laser to put them in the appropriate energy level, the team hit them with microwave radiation to induce some of them to jump to another energy level.

The researchers pinpointed the frequency of radiation needed to make the atoms take the leap, which is equivalent to finding the size of the gap between



the energy levels. While the frequency predicted from calculations was about 18,498 megahertz, the team measured about 18,501 megahertz, a difference of about 0.02 percent. Given that the estimated experimental error was only about 0.003 percent, that's a big gap.

The team did not find any experimental issues that could explain the result. Additional experiments are needed to investigate the mismatch, says physicist Akira Ishida of the University of Tokyo. "If there is still significant discrepancy after further precise measurements, the situation becomes much more exciting."

The theoretical prediction also seems solid. In quantum electrodynamics, making predictions involves calculating to a certain level of precision, leaving out terms that are less significant and more difficult to calculate. Those terms are expected to be too small to account for the discrepancy. But "it's conceivable that you could be surprised," says theoretical physicist Greg Adkins of Franklin & Marshall College in Lancaster, Pa.

If experiments and theoretical calculations check out, the discrepancy might be due to a new particle, but that also seems unlikely. A new particle's effects probably

would have shown up in earlier work. For example, Pérez Ríos says, positronium's energy levels could be affected by a hypothetical axion-like particle. That's a particle that has the potential to explain dark matter, an invisible type of matter thought to permeate the universe. But if that particle caused this mismatch, its effects would have been seen in measurements of the magnetic properties of the electron and its heavier cousin, the muon.

That leaves scientists still searching for an answer, says study coauthor David Cassidy. "It's going to be something surprising," he predicts. ■

## LIFE & EVOLUTION

# Poison may be making dingoes bigger

Body size increased after farmers started using a toxic bait

BY JAKE BUEHLER

Australia's dingoes are getting bigger, and it may be because of humans. New research suggests the change is happening only in places where the wild canine's populations are controlled with poison.

The findings could illustrate for the first time that pesticides can change the physical traits of large "pest" species.

"We've known for a long time that if we spray our fields with pesticides, then the insects that we're trying to kill change and develop resistance," says ecologist Michael Letnic of the University of New South Wales in Sydney. "This work suggests that when we use pesticides on big animals, we can produce comparable changes."

Dingoes (*Canis lupus dingo*), which attack livestock, have an uneasy relationship with farmers and ranchers in Australia. Shooting and fencing have long been used to control dingo populations. But in the 1960s and 1970s, people in western and southern Australia started using a poison called sodium monofluoroacetate, or 1080. Odorless and tasteless, the poison could be mixed into meat and scattered across the landscape as deadly bait.

A dose's effectiveness depends on a dingo's mass. That fact led Letnic to won-

der if the poison might be related to an observed increase in dingo size over time.

He and Mathew Crowther, an ecologist at the University of Sydney, delved into museum collections of dingo skulls, collected from three areas exposed to 1080 for about 50 to 60 years and one region where dingoes haven't been poisoned. The skulls date from 1930 to the present, so by measuring skull length (a proxy for body mass), the researchers could compare the sizes of animals before and after poisoning began.

After examining over 500 skulls, the team found that in baited regions, female skulls have grown 4.5 millimeters longer, on average, since 1080 was introduced. Male skulls are about 3.6 millimeters longer. These changes equate to roughly 6 and 9 percent jumps in body mass in males and females, or about a one kilogram increase on average, Letnic and Crowther report online July 31 in the *Biological Journal of the Linnean Society*. Dingo skulls in the unbaited region did not change over the same period.

Dingoes are top predators whose appetites send ripple effects through the food web. Kangaroo numbers increase when dingo populations are controlled, so the combination of extra prey availability and reduced competition may



Farmers in Australia view livestock-eating dingoes as pests that need to be controlled.

make it easier for dingoes that aren't killed by the poison to find food and grow bigger. "By reducing the dingo population, [1080 is] changing the environment that dingoes are growing up in," Letnic says. Bigger dingoes may then, in turn, be more tolerant of the poison.

The study is based on correlations rather than experimental manipulation of dingo populations, but the team's search for alternative explanations for the size increase came up short.

Kiyoko Gotanda, an evolutionary ecologist at the University of Cambridge, says she would "be interested to learn if changes to body size occur once you stop using poison control on the predators."

Dingoes may not be the only affected animal. 1080 is also used to control other pests, including invasive red foxes. If foxes become tolerant of 1080, Letnic says, the conservation consequences could be harsh. ■

## MATTER &amp; ENERGY

# Hot beads chilled faster than cool ones

A new experiment suggests that the Mpemba effect is real

BY EMILY CONOVER

In physics, chilling out isn't as simple as it seems. In a new study, a warmer system cooled off in less time than it took a cooler system to reach the same temperature.

The experiment, reported in the Aug. 6 *Nature*, was inspired by the Mpemba effect, the counterintuitive observation that hot water sometimes freezes faster than cold. But experiments studying this phenomenon have been muddled by the complexities of water and the freezing process, making results difficult to reproduce and leaving scientists disagreeing over what causes the effect, how to define it and if it is even real (*SN*: 2/4/17, p. 14).

To sidestep those complexities, physicists Avinash Kumar and John Bechhoefer of Simon Fraser University in Burnaby, Canada, used microscopic glass beads in lieu of water. And the pair defined the Mpemba effect based on cooling instead of freezing.

The result: "This is the first time that an experiment can be claimed as a clean, perfectly controlled experiment that demonstrates this effect," says theoretical chemist Zhiyue Lu of the University

of North Carolina at Chapel Hill.

A bead represented the equivalent of a single molecule of water, and measurements were performed 1,000 times under a given set of conditions to produce a collection of "molecules." A laser exerted forces on the bead, producing an energy landscape, or potential. Meanwhile, the bead was cooled in a bath of water. The effective "temperature" of the beads from the combined trials could be derived from how they traversed the energy landscape, moving in response to the forces imparted by the laser.

The beads began at either a high or a moderate temperature, and the researchers measured how long it took for the beads to cool to the temperature of the water. In certain scenarios, the hotter beads cooled faster, and sometimes exponentially faster, than the cooler beads. In one case, the hotter beads cooled in about two milliseconds; the cooler beads took 10 times as long.

It might seem sensible to assume that a lower starting temperature would provide an insurmountable head start in cooling: A hot object would first have to

reach the original temperature of a warm object, suggesting that a higher temperature could only add to the cooling time.

But that logic is wrong for systems that are not in a state of thermal equilibrium, in which all parts have reached an even temperature. As the beads cooled, their locations in the potential energy landscape weren't distributed in a manner that would allow a single temperature to describe them.

For such systems, rather than a direct path from hot to cold, there can be multiple paths, allowing for shortcuts. For the beads, depending on the shape of the landscape, starting at a higher temperature meant they could more easily rearrange themselves into a configuration that matched a lower temperature.

Physicist Oren Raz of the Weizmann Institute of Science in Rehovot, Israel, notes that "we don't know whether this is the effect in water or not." Water is more complex, including the quirks of evaporation and impurities in the water.

But the simplicity of the study is part of its beauty, says theoretical physicist Marija Vucelja of the University of Virginia in Charlottesville. "It's one of these very simple setups, and it already is rich enough to show this effect." That suggests the Mpemba effect could go beyond glass beads or water, she says. ■

## MATH &amp; TECHNOLOGY

## A new beetle bot is free to roam

A robot beetle goes the distance on its own thanks to a methanol-fueled micromuscle.

Scientists envision that swarms of robotic insects could assist search-and-rescue operations. But tight spaces are out of reach for robots that must be tethered to an energy source. The new bot, described August 19 in *Science Robotics*, carries its liquid fuel inside its body. Methanol, for a given mass, packs over 10 times the energy of a tiny battery.

To turn methanol into motion, researchers coated a nickel-titanium alloy wire with platinum. The alloy contracts like a muscle when heated and extends once cool. The platinum generates heat by combusting any methanol vapor it comes into contact with. By varying the exposure to fuel in a periodic pattern, the temperature varies and the micromuscle accords. That motion causes the bot's

forelegs to rear up. When the legs scooch back again, the body drags forward.

Excluding fuel, the beetle bot (shown below) weighs about as much as three grains of rice, on par with real insects. It can tackle inclines steeper than the toughest treadmill setting and run for over one hour, says engineer Néstor O. Pérez-Arancibia of the University of Southern California. Even with the best miniature battery, the bot would run for a few seconds at best, he estimates.

— Carmen Drahl



See a beetle bot in action at [bit.ly/SN\\_BeetleBot](http://bit.ly/SN_BeetleBot)

## LIFE &amp; EVOLUTION

## X-rays unwrap animal mummies

With scans, scientists identify species and cause of death

BY HELEN THOMPSON

Egyptian animal mummies can look like little more than bundles of cloth. High-tech X-rays have unveiled some of the mysteries surrounding three such mummies: a cat, a bird and a snake.

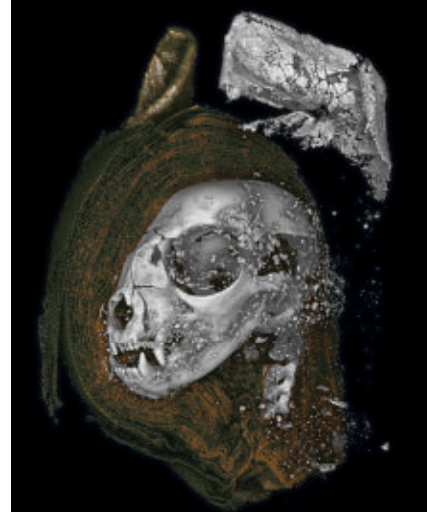
Two-dimensional X-rays of each specimen had provided little information beyond generic animal labels. So engineer Richard Johnston of Swansea University in Wales and colleagues used a microCT scanner to get a better look.

Scans of the bones gave such detail that researchers could tentatively identify the cat as a domestic kitten (*Felis catus*). The bird most closely resembled a Eurasian

kestrel (*Falco tinnunculus*), and the snake was likely an Egyptian cobra (*Naja haje*), the team reports August 20 in *Scientific Reports*. Possible cause of death was clear in two cases: The kitten appeared to have been strangled, and the snake had its spine broken. The snake also had kidney damage, perhaps from water deprivation. These three animal mummies may have been offerings to gods.

Scanning sections instead of the whole mummy at once allowed the team to get increased detail and create models of the remains that could be 3-D printed and investigated through virtual reality. That's how the team found the kitten's unerupted molars, a clue that the cat was less than 5 months old.

The team's approach to using microCT scanning to study mummies has potential "to improve our understanding of this ancient practice," says archaeologist Lidija McKnight of the University of Manchester in England. Scans of the



MicroCT scanning allowed scientists to create this 3-D model of a cat wrapped in cloth and mummified by ancient Egyptians.

snake hint at an Egyptian ritual previously seen primarily in human mummies. The snake had what looked like mineral structures in its open mouth. Embalmers often opened the mouths and eyes of mummies so the dead could see and communicate. Snakes may have also whispered beyond the grave, as a messenger between the gods and a worshipper. ■

## LIFE &amp; EVOLUTION

## Ichthyosaur gobbled a supersized meal

Ancient reptile died after eating an animal nearly as long as itself

BY MARIA TEMMING

For its last meal, an ancient marine reptile called an ichthyosaur may have bitten off more than it could chew.

The critter, which resembled a dolphin, was nearly 5 meters long, about the length of a canoe. Its belly contained the remains of a lizardlike reptile called a thalattosaur that was almost as long: 4 meters. This is the longest known prey of a marine reptile from the dinosaur age, and may be the oldest direct evidence of a marine reptile eating an animal larger than a human, researchers report August 20 in *iScience*. The prey may have been such a big meal that it killed the ichthyosaur.

The ichthyosaur's blunt teeth suggest it should have favored small, soft prey like cephalopods (*SN: 10/28/17, p. 16*). "Now we have really solid evidence saying these [blunt] teeth can be used to eat something big," says Ryosuke Motani, a paleobiologist at the University of

California, Davis. "That means the other species with similar teeth we discounted before ... may be megapredators too."

Motani and colleagues examined the nearly complete skeleton of a roughly 240-million-year-old adult ichthyosaur, from the genus *Guizhouichthyosaurus*, unearthed in China. The team found that the last thing the ichthyosaur ate was the thalattosaur, sans head and tail. The remains show little evidence of being degraded by stomach acid, hinting the ichthyosaur died shortly after its meal.

The fossils offer "pretty good evidence that the bigger animal ate the smaller one," says vertebrate paleontologist Steve Brusatte of the University of Edinburgh. "If this really is the case, it's quite stunning." Although the ichthyosaur was not much longer than its prey, the predator was perhaps about seven times as massive as the whip-thin thalattosaur.

Motani's team thinks the ichthyosaur

hunted, rather than scavenged, its meal. For one thing, it would have been unusual to come across a whole dead animal that no other predator had gobbled up. Plus, the thalattosaur's limbs were still at least partially attached to the body, while the fossilized tail was uncovered about 20 meters away. Studies of how bodies decompose underwater suggest that if the prey was a carcass when the ichthyosaur found it, the limbs would have rotted off before the tail, the researchers argue.

The ichthyosaur appears to have died from a broken neck. That injury could have occurred while the animal was holding the thalattosaur in its jaws and thrashing its head, how crocodiles and killer whales rip up food without having very sharp teeth, Motani says.

Or the ichthyosaur could have hurt itself while swallowing. "This is not a snake that's adapted to swallow something really big," Motani says. That means swimming against its prey to shove the food down its throat, or sticking its head above water and using gravity to gulp the meal down. "It could easily damage its neck doing this." ■



Hop plants grown in Washington's Yakima Valley have a distinct chemical composition due to the soil, weather and how the plants grow.

# What place means for taste

A crop's environment can leave a lasting mark

By Carolyn Beans

About seven years ago, Kristin and Josh Mohagen were honeymooning in Napa Valley in California, when they smelled something surprising in their glasses of Cabernet Sauvignon: green pepper. A vintner explained that the grapes in that bottle had ripened on a hillside alongside a field of green peppers. “That was my first experience with terroir,” Josh Mohagen says.

It made an impression. Inspired by their time in Napa, the Mohagens returned home to Fergus Falls, Minn., and launched a chocolate business based on the principle of terroir, often defined as “sense of place.”

Different countries produce cocoa with distinct flavors and aromas, Kristin Mohagen says. Cocoa from Madagascar “has a really bright berry flavor, maybe raspberry, maybe citrus,” she says, while cocoa from the Dominican Republic “has a little more nutty, chocolaty taste.”

The couple estimates that back in 2013, when they founded Terroir Chocolate, about 50 other small batch chocolate companies in the United States were also touting terroir as integral to their products' flavors.

Since then, terroir has continued to take hold as a marketing strategy — and not just for wine and chocolate. Terroir labels are also becoming more common for products like coffee, tea and craft beer, says Miguel Gómez, an economist at Cornell University who studies food marketing and distribution. Consumers “are increasingly interested in knowing where the products they are eating are produced — not only where but who is making them and how,” he says. People “value differences in the aromas, the flavors.”

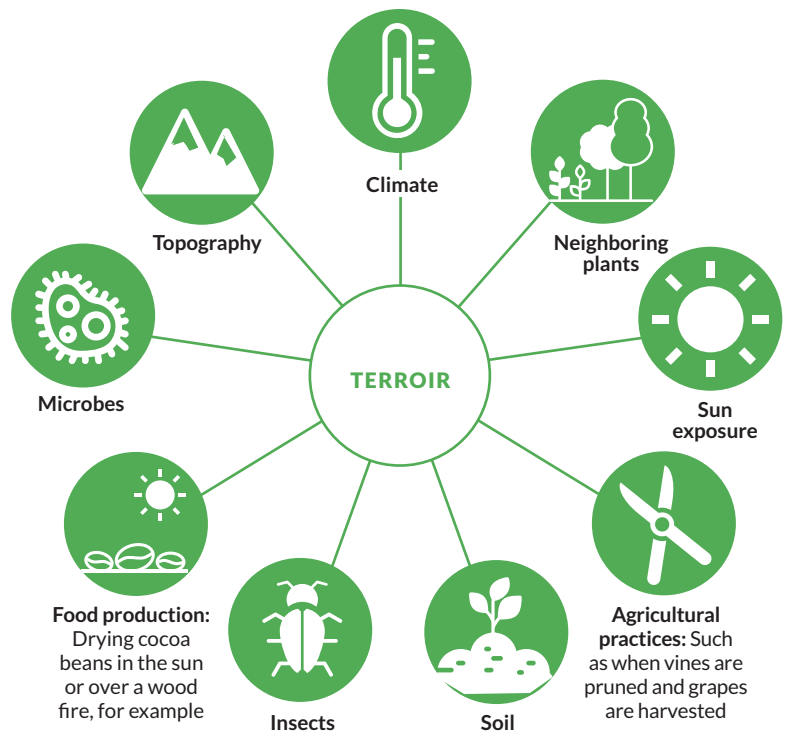
The definition of terroir is somewhat fluid. Wine enthusiasts use the French term to describe the environmental conditions in which a grape is grown that give a wine its unique flavor. The soil, climate and even the orientation of a hillside or the company of neighboring plants, insects and microbes play a role. Some experts expand terroir to include specific cultural practices for growing

and processing grapes that could also influence flavor.

The notion of terroir is quite old. In the Middle Ages, Cistercian and Benedictine monks in Burgundy, France, divided the countryside into *climats*, according to subtle differences in the landscape that seemed to translate into unique wine characteristics. Wines produced around the village of Gevrey-Chambertin, for example, “are famous for being fuller-bodied, powerful and more tannic than most,” says sommelier Joe Quinn, wine director of The Red Hen, a restaurant in Washington, D.C. “In contrast, the wines from the village of Chambolle-Musigny, just a few miles south, are widely considered to be more fine, delicate and light-bodied.”

Some scientists and wine experts are skeptical that place actually leaves a lasting imprint on taste. But a recent wave of scientific research suggests that the environment and production practices can, in fact, impart a chemical or microbial signature so distinctive that scientists can use the signature to trace food back to its origin. And in some cases, these techniques are beginning to

**What is terroir?** Scientists and food enthusiasts point to many components of place that may shape the aroma and flavor of food.



offer clues on how terroir can shape the aroma and flavor of food and drink.

### Coffee's chemical fingerprint

Ecologist Jim Ehleringer of the University of Utah in Salt Lake City studies trace elements that plants passively take up. Those elements are a direct reflection of the soil. “Trace elements do not decay and so they become characteristic of a soil type and persist over time,” Ehleringer says.

To see if they could trace a coffee to its origin using the coffee's blend of trace elements, Ehleringer and his team recently measured the concentrations of about 40 trace elements in more than four dozen samples of roasted arabica coffee beans from 21 countries. Roasting beans to different temperatures can affect the concentrations of individual elements. To correct for this roasting effect, Ehleringer calculated the ratio of each element to every other element in a sample, which remains fairly constant, even with roasting.

In the Aug. 1 issue of *Food Chemistry*, his team reports that coffee beans from different regions can have distinct chemical fingerprints. A coffee's chemical quality “comes down to geology,” Ehleringer says. Three samples of coffee beans from Yemen, for example, had a ratio of boron to manganese that was shared by less than 0.5 percent of coffee samples grown elsewhere.

Other researchers have used similar elemental analyses to find chemical signatures of place in products ranging from wines produced in distinct growing regions in Portugal to peanuts grown in

different provinces in China.

The technique is valuable for validating origin when terroir is part of a product's allure. Coffee farmers in Kona on Hawaii's Big Island, for example, are using the results of an elemental analysis to support a class action lawsuit, scheduled for trial in November, against 21 major retailers. The suit claims those companies falsely market their coffees as “Kona” when the beans were actually grown elsewhere.

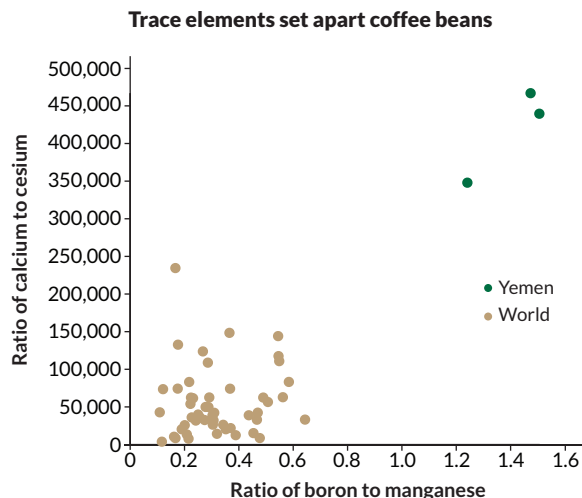
While an elemental analysis can authenticate a product's terroir, it does not suggest that geology shapes flavor. Trace elements alone, says Ehleringer, “impart no flavor or taste.”

### Tracking cocoa to its source

To try to link flavor to place, some scientists go after different chemical signatures altogether. At Towson University in Maryland, chemist Shannon Stitzel is tracing cocoa to its roots using organic compounds, which are mostly produced by the cocoa plant itself. The concentration of specific organic compounds in a plant can result from a complex mix of interacting factors — from the genes of a particular variety to components of terroir like climate and agricultural practices.

Stitzel works with samples of cocoa liquor — cocoa beans that have been fermented, dried, roasted and ground into a paste — from across the globe. At room temperature, cocoa liquor is a solid. But with a bit of heat, the paste melts into a glossy liquid that Stitzel describes as “a little thicker than honey.”

**Trace differences** Coffee beans, like those grown by farmers in Yemen (left), have distinct concentrations of trace elements, depending on where the beans were grown. The ratios of boron to manganese and calcium to cesium are enough to distinguish Yemeni coffee beans from those grown in other parts of the world (right).



SOURCE: N.Q. BITTER ET AL/FOOD CHEMISTRY 2020

Using organic compounds to assign the cocoa liquor samples to their countries of origin is “not nearly as clean as when you do it with elemental analysis,” she says. In unpublished work, she was able to use an elemental analysis to accurately link cocoa liquor to its country of origin about 97 percent of the time.

But Stitzel turned to organic compounds because their presence may ultimately help explain the flavor differences that she, like the Mohagens, thinks very clearly exist between cocoa liquors from different countries. “You can open up each of the containers and the aroma is entirely different,” she says.

Stitzel recently identified concentrations of organic compounds in cocoa liquor from Vietnam, Indonesia, Honduras, Ecuador and Mexico. She then used a statistical technique known as a discriminant analysis to group samples based on similar concentrations of nine organic compounds, including caffeine, a similar compound called theobromine and an antioxidant called epicatechin.

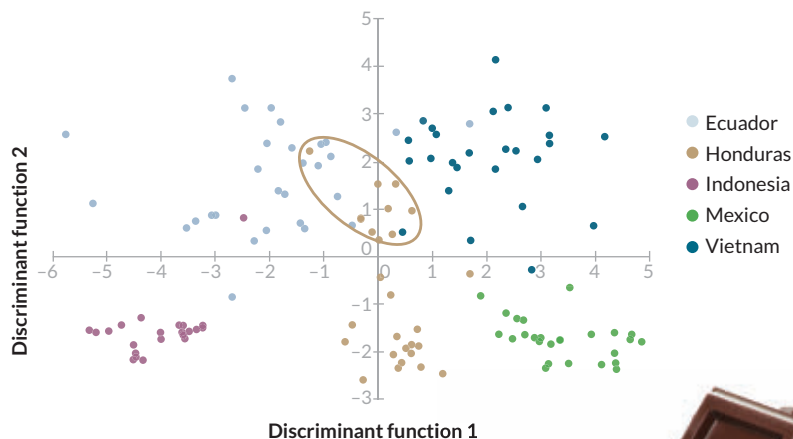
On the American Chemical Society’s SciMeetings online platform in April, Stitzel reported that this chemical fingerprint was enough to accurately identify the correct country of origin for about 90 percent of the samples. In some cases, however, the samples didn’t form neat groups by country. Cocoa liquor samples from Honduras formed two different groups, depending on roasting temperature. Samples in the Honduras group that were roasted at the highest temperature were hard to tell apart from samples from Ecuador and Vietnam.

Stitzel now wants to add more compounds to the analysis to boost her sourcing accuracy and to connect regions to specific flavor compounds. “We’re still ... trying to understand which compounds might be related to flavor,” she says. Her recent analysis already shows that caffeine, theobromine and epicatechin, which all produce a bitter flavor, can help set apart one country’s chocolates from another’s.

### The aroma of place

Other researchers are finding that terroir leaves an imprint on the molecules that shape food’s aroma. Plants produce compounds known as aroma glycosides, which contain a sugar component linked to a volatile aromatic compound. When intact, aroma glycosides have no scent. But breaking the sugar-volatile bond — via high temperatures, low pH or enzymes from yeast —

Analysis of organic compounds in cocoa liquor by country



**The roasting effect** Using a statistical technique known as a discriminant analysis, researchers grouped cocoa liquor samples according to similarities in the concentrations of nine organic compounds. Each country’s samples clustered together, except for those in the Honduras group that were roasted at the highest temperature; they overlapped (circled) with samples from Ecuador and Vietnam.

sets the volatile and its aroma free. The bouquet of a nicely aged bottle of wine is made up, in part, of aroma volatiles in the grapes that yeast enzymes let loose over time.

Many beer brewers, however, would rather your IPA have the same reliable flavor whether you pop open the bottle this Friday or in October. When volatile aromatics let loose in a bottled beer, that’s no good for large-volume brewers who need to ship consistent-tasting products. Brewers call that volatile release “beer creep,” says Paul Matthews, a senior research scientist in the Washington state branch of Hopsteiner, an international commercial hop grower and processor headquartered in New York City.

If brewers add hops (the flower of the hop plant) to beer early in the brewing cycle, heat breaks the sugar-volatile bond and the aroma from aroma glycosides is largely lost before bottling. The remaining flavor is more consistent over time. But when craft brewers make “dry hopped” beers like IPAs, adding the hops after the boiling stage, this late addition allows many aroma glycosides to go into fermentation and then into the bottle intact. The compounds release volatile aromatics as yeast enzymes break bonds even after the bottle is capped. So the aromas of these beers are more likely to “creep” over time.

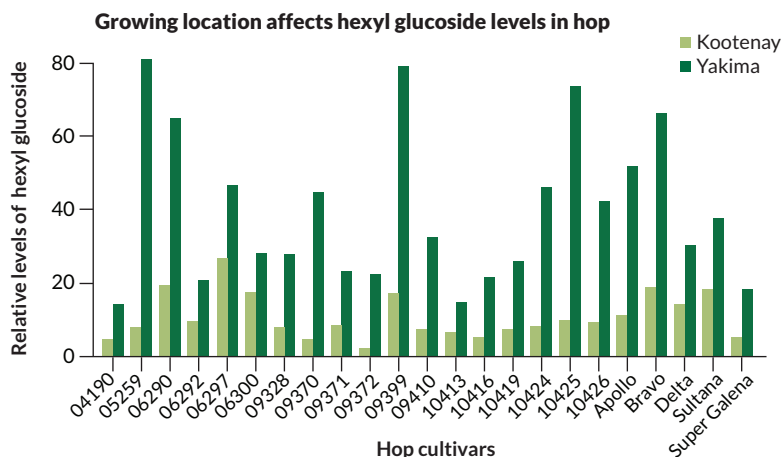
Because genetics influences aroma and flavor, Matthews is exploring whether it’s possible to better control aroma glycoside concentrations through breeding. Breeding hop varieties



to have lower concentrations could diminish the “beer creep” problem faced by large-volume craft brewers who distribute their beer over long distances.

At the same time, Matthews and colleagues are investigating the potential of breeding hop varieties to have higher aroma glycoside concentrations for use by smaller craft brewers, who are less concerned about shelf life but want to enhance the aroma of their beers.

Matthews recently tested whether aroma glycoside concentrations in individual hop cultivars are determined more by genetics or by terroir. “Of course, they are determined by both,” he says. “But if they are more genetic, we can breed for them.”



**Terroir trumps genetics** Hop plant cultivars grown in Washington’s Yakima Valley (shown above) produce higher levels of hexyl glucoside than the same cultivars grown in Idaho’s Kootenay River valley. The reason may be mites and aphids.

SOURCE: T.B. MORCOLET AL/FOOD CHEMISTRY 2020

In collaboration with colleagues, including phytochemist Taylan Morcol of Lehman College in the Bronx, part of the City University of New York, Matthews grew the same 23 genetically distinct hop cultivars at two commercial fields with distinct terroirs. Matthews calls the Yakima Valley site in Washington state “desert in the shadow of Mount Rainier.” The other site, in the Kootenay River valley in Idaho, is “much more boreal — pine forest and humid,” he says.

At each location, the team measured the concentrations of four aroma glycosides in each hop cultivar. Genetics indeed played the biggest role in determining how much aroma glycosides a hop plant produces, the researchers report in the Aug. 15 *Food Chemistry*. The concentrations of three of the aroma glycosides differed across cultivar types but remained fairly similar within the same cultivar grown in the two locations.

But for one aroma glycoside, terroir trumped genes in a big way. At the Kootenay site, all of the cultivars produced low concentrations of hexyl glucoside, a molecule that gives off a grassy aroma when its sugar bond is broken. But at the Yakima site, every one of these same cultivars, with genetics matching the plants in Kootenay, produced about two to eight times as much hexyl glucoside.

“There is a terroir difference,” Matthews says. The team can’t yet pinpoint which component of terroir causes the spike in hexyl glucoside at the Yakima site. The best guess: mites and aphids.

At Yakima, those critters, which munch on the hop plants, hang around for a longer portion of the growing season than at the Kootenay site. Matthews and his colleagues hypothesize that the plants might produce hexyl glucoside chemicals as a defense against the pests. When a mite or aphid munches on the plant, the volatile may be released to attract insects that will eat the mites or aphids.

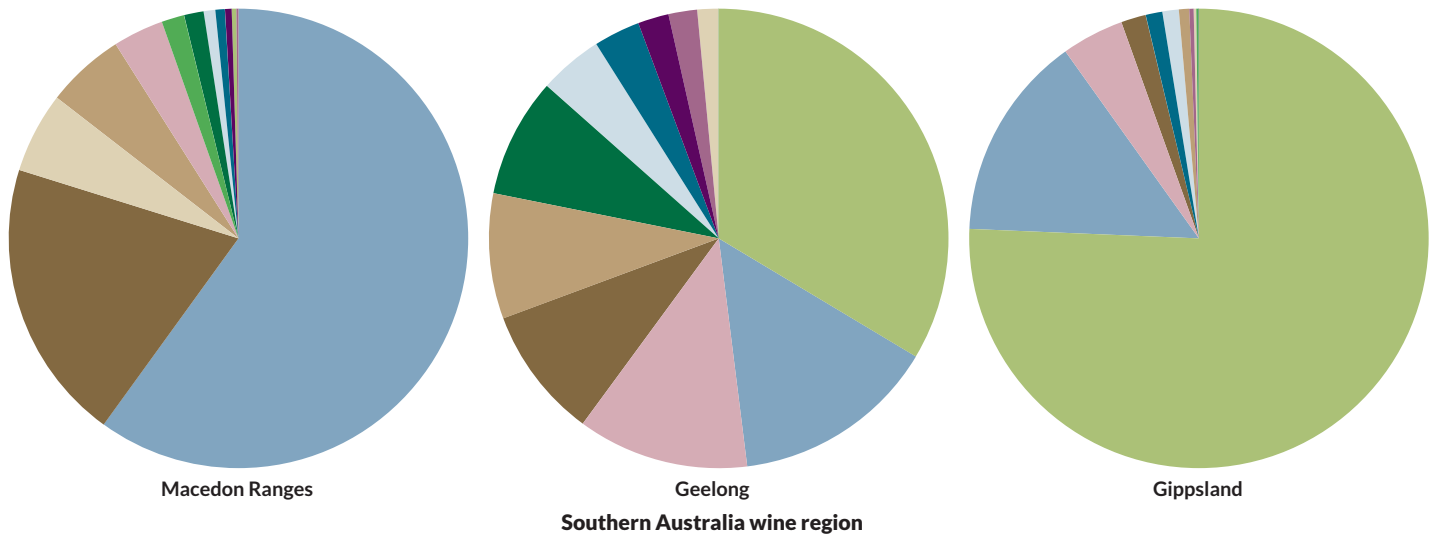
The researchers are planning a follow-up experiment to test whether hop plants exposed to these pests in environmentally controlled chambers produce more of this grassy hexyl glucoside than hop grown under the same environmentally controlled conditions without the pests.

**Microbes leave their mark**

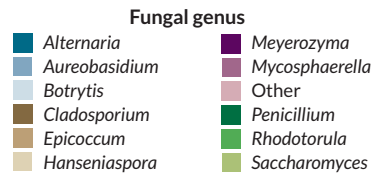
People have understood the importance of yeast in wine fermentation for at least two centuries. About six years ago, food microbiologist David Mills of the University of California, Davis and graduate student Nicholas Bokulich, now a food microbiologist at ETH Zurich, discovered that groups of microbes may help shape the flavor

FROM TOP: NICHOLAS J. PITRA AND P.D. MATTHEWS/HOPSTEINER; E. OTWELL





**Fungal distinctions** The diversity of yeast and other fungi found in grape must (the crushed grapes that haven't yet been fermented) differs across distinct wine growing regions in southern Australia that produce Pinot Noir grapes (some shown, right). Researchers linked these fungal communities to distinct collections of metabolites that affect aroma and flavor in the finished wine. SOURCE: D. LIU ET AL./MSPHERE 2020



of wine. Unique microbial communities in different California growing regions can predict which metabolites will be present in the finished wine, Mills, Bokulich and colleagues reported in 2016 in *mBio*. “Metabolites are any product of metabolism in any organism,” Bokulich says, adding that yeast, other fungi and bacteria each make varying contributions of metabolites in different wines.

“Those metabolites ... have an aroma and a flavor,” says Kate Howell, a biochemist at the University of Melbourne in Australia. One of Howell’s own studies, she and her team reported online in August in *mSphere*, suggests that fungal species in particular shape the metabolites — and thus aroma and flavor — in wine from different growing regions in Australia.

Howell and colleagues studied microbes at 15 vineyards growing Pinot Noir grapes across six wine regions in southern Australia. At each vineyard, the team extracted fungal and bacterial DNA from the soil, as well as from what’s known as the “must” — destemmed, crushed grapes that haven’t yet been fermented. Then, the team identified 88 metabolites in the finished wine.

Different wine growing regions had distinct microbial communities in both the soil and the must, which appeared to influence the unique compositions of metabolites in the finished wine. The researchers found that over 80 percent of the metabolites found in the various wines were linked to the diversity of fungi found in the grape must. High levels of *Penicillium* fungi, for example,

resulted in wine with low levels of octanoic acid, a volatile compound that can give wine a mushroom flavor.

Howell hopes vintners may someday be able to manage microbes in the soil and throughout the fermentation process to bring out the best of the local microbial terroir. Today, nearly all of the yeasts that vintners purchase to add to their grape must are isolated from French vineyards and other famous wine regions, she says. “That doesn’t present the same value of place as encouraging diversity in the fermentation in the place that the grapes were grown.”

For his part, Quinn, of The Red Hen, eagerly awaits more scientific explorations of terroir. He would especially like to know why wines produced from the limestone-dominated Kimmeridgian soils in Chablis, Sancerre and Champagne, France, all have a chalky, saltlike mineral taste. Scientific research helps explain how wine reflects its place, Quinn says, “from the climatic elements to the microbial elements, what the earth is saying, and why [a particular] wine is so delicious.” ■

**Explore more**

- Taylan B. Morcol *et al.* “Hop (*Humulus lupulus* L.) terroir has large effect on a glycosylated green leaf volatile but not on other aroma glycosides.” *Food Chemistry*. August 15, 2020.

*Carolyn Beans is a freelance science reporter based in Lancaster, Pa.*

FROM TOP: E. OTWELL; D. LIU



FEATURE

In March 2019, the U.S. Supreme Court heard expert testimony on how to test for partisan skew in the way district maps are drawn. Protesters (shown) demanded an end to gerrymandering.

# CALLING OUT Gerrymandered MAPS

## Analyses of alternative district maps point out hidden bias

By Sujata Gupta

In October 2019, a state court determined that North Carolina's congressional districts had been severely gerrymandered and struck down the state's map. The court's ruling was informed, in part, by tens of thousands of alternative maps demonstrating that the district boundaries had very likely been manipulated for political gain, the very definition of gerrymandering.

Researchers had generated a slew of alternative, computer-generated maps designed to help identify potential patterns of bias. The approach is increasingly used, alongside other tests, to ferret out alleged gerrymandering. District manipulations can be so subtle that they're undetectable just by looking at them. "The eyeball test is no good," says Jonathan Katz, a political scientist and statistician at Caltech.

U.S. states redraw their district lines every 10 years to adjust for changing demographics picked up by the national census.

The last round a decade ago raised eyebrows, most notably for districts drawn in Michigan, North Carolina and Pennsylvania.

"The post-2010 round of redistricting is widely viewed as a time of extreme, even egregious, partisan gerrymandering," retired political scientist Richard Engstrom wrote in the January 2020 *Social Science Quarterly*.

A 2017 report by the nonpartisan Brennan Center for Justice at New York University School of Law noted that existing congressional maps were largely biased in favor of the Republican Party. In 26 states, which account for 85 percent of U.S. congressional districts, as many as 17 Republicans in the House of Representatives owe their seats to gerrymandering. In states where Democrats controlled the redistricting process, partisan bias is also a problem, but the effect is smaller because those states are often made up of fewer districts.

Since 2011, legal scholars, political scientists and mathematicians conducting gerrymandering research have served as expert witnesses in more than 250 state and federal court cases regarding redistricting.

With the 2020 U.S. census now under way, legislators will soon be revising electoral districts again. This time around, researchers hope that instead of serving as expert witnesses in court, they can help identify problematic districting before the new maps even go into effect.

"In 2010, the politicians were thinking very hard on how to draw maps," while the public and academics weren't paying a lot of attention, says Jon Eguia, an applied game theorist at Michigan State University in East Lansing. "So in 2011, [those politicians] drew a lot of very bad maps in very many states. Now we're all paying attention."

EVELYN HOCKSTEIN/THE WASHINGTON POST/GETTY IMAGES

## Measuring bias

According to the U.S. Constitution and the Voting Rights Act of 1965, a state's voting districts must each contain about the same number of people and be drawn in a way that doesn't disenfranchise racial or ethnic minorities. States can have additional rules, such as contiguity of districts or that cities or counties be kept intact.

That leaves two main tactics for gerrymandering: "packing" the opposing political party's supporters into a few districts in hopes your party dominates the rest, or "cracking" these supporters by spreading them across many districts to dilute their collective voting power. Those skilled in gerrymandering draw district boundaries that ensure decade-long protection for the ruling party.

Early methods to test a state map for gerrymandering, which are still in use today, rely on a concept known as partisan symmetry. If a map provides symmetric, or equal, opportunity for all parties in a contest to convert votes into seats, that map is deemed fair. States with packed and cracked districts won't pass tests based on symmetry.

Symmetry-based tests gained prominence after *LULAC v. Perry*, a 2006 Supreme Court case that reviewed a mid-decade redistricting plan in Texas. In that case, scientists entered into evidence a partisan bias test — a simulation of what would have happened in an election if the parties' vote shares were reversed. For instance, if Party A wins 10 out of 15 seats with 70 percent of the vote in an actual election, then Party B, in a hypothetical election, should win 10 seats if it had 70 percent of the vote. Deviation from that "symmetry" equals the level of partisan bias.

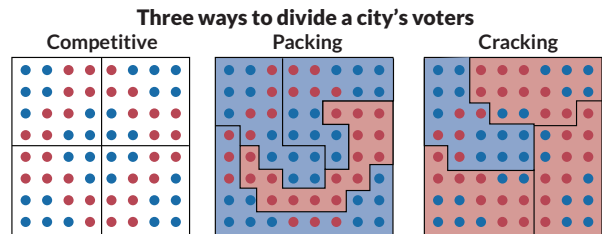
In *LULAC*, the justices largely upheld Texas' map. But the court indicated willingness to use a symmetry-based method in a future case, though perhaps not solely the partisan bias test. Justice Anthony Kennedy expressed concerns about that particular test, saying it was unclear how much bias was too much. Kennedy also questioned the method's reliance on statistical simulations rather than real-world results. "We are wary of adopting a constitutional standard that invalidates a map based on unfair results that would occur in a hypothetical state of affairs," he wrote in the plurality opinion for *LULAC*.

## Real-world symmetry

Kennedy's feedback on *LULAC* prompted researchers to develop other symmetry-based tests that used actual election results.

One such approach is the median-mean difference test. That test arises from the basic statistical principle that the difference between the median and the mean indicates the level of skew in the data, with values closer to zero less skewed and vice versa. In 2015 in the *Election Law Journal*, political scientists Michael McDonald and Robin Best of Binghamton University in New York explained how a median-mean analysis could help identify partisan skew in a state.

A party's mean vote share comes from averaging vote shares



**Puzzle power** The party that controls the maps can grab power through packing or cracking. In packing, politicians cram voters from the opposing party into just a few districts, securing the remaining districts for their own party. The blue ruling party (above, center) created one all-red district, and three majority blue districts. In cracking, politicians spread voters from the opposing party across districts, blocking them from gaining a majority. The ruling red party split up blue voters at the "city center" to create three reliably red districts (right). SOURCE: AZAVEA 2018

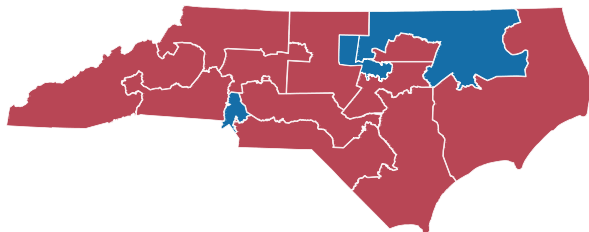
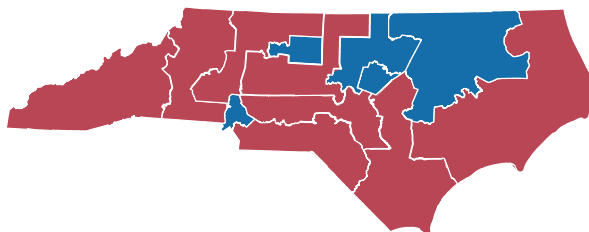
across all districts in a state. A party's median vote share comes from the district in the middle of a distribution, with the party's worst-performing district in terms of vote share at one end and the best-performing district at the other. If the difference between a party's median and mean vote shares is high, that indicates a possibly biased skew, though McDonald and Best noted that some natural skew is inevitable and must be factored into any analysis.

Another approach is called the efficiency gap, which measures the difference in packing and cracking between parties by tallying "wasted" votes. So, if Party A draws an electoral map that spreads Party B's voters across districts, votes cast for Candidate B in districts won by A are wasted. Conversely, if Party A packs Party B's voters into a few districts, votes cast for Candidate B beyond the majority needed to win are also wasted. Each party should have about the same number of wasted votes in an election. So the efficiency gap, first described in 2015 in the *University of Chicago Law Review*, is calculated by taking the difference in wasted votes between parties and dividing that by the total number of votes cast.

PlanScore, a nonpartisan group of legal, political and mapping experts, has shown how the various symmetry tests can be used in tandem to flag possible gerrymandering. In its analysis of the congressional map used in North Carolina's 2018 congressional elections, where Republicans won 10 seats and Democrats three, PlanScore found bias using all three tests: The partisan bias test showed that in a hypothetical, tied election, Republicans would win 26.9 percent extra seats. In the median-mean test, the median Republican vote share was 5.8 percent higher than its mean vote share. And the efficiency gap was 27.7 percent in favor of Republicans.

## Natural advantage

Critics of symmetry-based tests, though, say that the presence of packing and cracking does not prove that the governing party has intentionally gerrymandered the state's districts. Instead, asymmetries can also arise from natural variations in where voters live. Crucially, Republicans tend to be more dispersed across states while Democrats are concentrated in cities.

**North Carolina congressional map, 2016 and 2018****North Carolina congressional map, 2020**

**Slightly fairer** For the last decade, Republican legislators in North Carolina have strategically packed and cracked Democratic voters across congressional districts, limiting their voting power. A state court struck down the maps from 2016 and 2018 (top) that created only three Democratic-leaning districts (blue). The 2020 map (bottom) creates two more blue-leaning districts, but researchers say the new map still gives Republicans an extra one or two seats.

SOURCE: NORTH CAROLINA GENERAL ASSEMBLY

“The party that’s more spread out has a geographic advantage,” says applied mathematician Jonathan Mattingly of Duke University. “That’s our system.”

Tests that have emerged over the last few years, known broadly as ensemble methods, accept that natural advantage. These tests rely on computers to generate thousands, or even millions, of possible maps. The programs draw myriad boundary lines around a given district and estimate which party would win that district under each scenario.

Consider a state in which one party wins four to seven seats in almost all maps generated, while the state is using a map that regularly gives that party nine seats, Eguia says. That discrepancy suggests partisan gerrymandering.

Lawyers working on gerrymandering cases tend to use ensemble and symmetry methods in tandem, says Ruth Greenwood, an attorney in Cambridge, Mass., with PlanScore and the nonpartisan nonprofit Campaign Legal Center. That’s because each alternative map can also be evaluated for symmetry using the various tests. Averaging symmetry scores in the ensemble maps and comparing those values with the symmetry scores of the real-life map can illuminate when the difference is stark and therefore can’t be chalked up to any “natural advantage.”

Using all methods together also means that when a map’s fairness is questioned, the lawyers can show that “on any metric, the result is terrible,” Greenwood says.

**States at the helm**

The issue of gerrymandering was weaving through the federal courts until June 2019, when the Supreme Court ruled 5–4

in *Rucho v. Common Cause* that partisan gerrymandering fell outside federal jurisdiction. The decision was in response to an appeal challenging a federal court’s January 2018 ruling that North Carolina’s congressional district map had been gerrymandered along partisan lines, giving Republicans 10 out of 13 seats in 2016 and 2018, despite the fact that in both elections Republicans won only about half the popular vote.

By removing the federal court system from gerrymandering cases, the Supreme Court left the issue to the states, a charge a North Carolina state court quickly took up in *Harper v. Lewis*. The state court relied on much of the same evidence presented in *Rucho*. That evidence included testimony by Mattingly showing that in a universe with 24,518 alternative congressional district maps, the map North Carolina was using was an egregious outlier. In the maps Mattingly generated, Republicans carried 10 or more seats less than 1 percent of the time.

In October 2019, the three-judge panel in the *Harper* case ruled that state lawmakers needed to redraw the congressional district map for 2020. Plaintiffs, however, then challenged the state’s remedial map, which would likely result in Republicans winning eight out of 13 seats. Mattingly again provided expert testimony, this time adding 57,202 more maps made using less stringent constraints than the first batch. His research showed a much more purple state, with a 7–6 or 6–7 party split arising in the majority of those alternative maps.

But with the state’s 2020 primary fast approaching, a state court approved the remedial map in December 2019. That new map will stand for only a short time, though. Along with every other state, North Carolina will go through redistricting again in 2021 after the census tallies are in. New Jersey and Virginia — which hold statewide elections in odd years — may struggle to finish their maps before the 2021 elections, since the census was delayed due to the pandemic.

Meanwhile, census watchers worry that the Trump administration’s recent decision to move the completion deadline for the population count from October 31 to September 30 could lead to undercounts among hard-to-reach groups, thereby affecting the placement of district boundaries.

Greenwood expects a spike in lawsuits, though now at the state rather than federal level, challenging the newly drawn maps. And a small cadre of researchers is now ready to serve as expert witnesses in those cases, Eguia says.

The upcoming mapmaking process doesn’t have to repeat the mistakes of a decade ago, he adds. In 2011, lawmakers drew maps largely behind closed doors without researchers present — resulting in a decade of lawsuits, he says. Why not, instead, bring researchers into the room, with their tests and myriad maps, from the get-go? “That’s what the community of experts would prefer,” he says. “That’s what I would advocate for.” ■

**Explore more**

■ Lauren Royden and Michael Li. “Extreme Maps.” Brennan Center for Justice at New York University School of Law. 2017.

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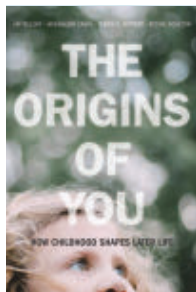
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**The Origins of You**  
Jay Belsky, Avshalom Caspi, Terrie E. Moffitt and Richie Poulton  
HARVARD UNIV., \$35

## BOOKSHELF

## Long-term research shows how kids develop into their adult selves

Everyone has an opinion about what makes people, especially the troublemakers, who they are. Bad parents, bad genes, bad society, bad luck, bad decisions — pick your poison.

Starting several decades ago, four psychologists decided to examine how individuals flourish or flounder over

the long run. Instead of jumping into a seemingly endless academic scrum over “nature versus nurture,” they studied how children actually develop over years and decades. Jay Belsky, Avshalom Caspi, Terrie Moffitt and Richie Poulton describe provocative insights from their investigations in *The Origins of You*.

Developmental researchers acknowledge that many personal and social factors interact throughout life. No single factor can explain, say, why one person pursues a life of crime and another excels in college. Life events and random circumstances tug kids in different directions, making various outcomes more or less probable but never dictating outcomes, the authors emphasize.

Only prospective studies can begin to illuminate the winding paths youngsters travel to become their adult selves. Much of *The Origins of You* concerns a project — now run by Caspi, Moffitt and Poulton — that has assessed about 1,000 New Zealanders in the town of Dunedin from birth to age 38 (data to age 45 is coming soon). The book also focuses on a study, started by Moffitt and Caspi, that has evaluated more than 1,000 pairs of British twins from ages 5 to 18, as well as another study, in which Belsky was involved, that followed about 1,300 U.S. children from birth to age 15. These investigations are among the few that have assessed a range of psychological and physical measures from childhood into adolescence and beyond.

One intriguing finding from these studies suggests that only certain childhood temperaments influence teenage personality and behavior. Dunedin kids deemed “undercontrolled,” irritable and distractible, at age 3 were typically impulsive and danger-seeking at age 18. “Inhibited” youngsters, however, tagged as shy, fearful and unresponsive to others at age 3, later were generally restrained and passive with others. Those two groups made up just 18 percent of the Dunedin sample.

Children play an active part in shaping their social worlds, likely explaining in large part why these particular childhood temperaments were so closely aligned with later personality, the authors suggest. Long-term Dunedin data indicate, for instance, that undercontrolled kids provoked hostility in parents, peers and teachers. A vicious cycle of rejection



A child's temperament during the preschool years is often not a good predictor of later personality, a study done in New Zealand suggests.

by others played out in which undercontrolled youngsters never had opportunities to learn social skills and self-control. Inhibited children, in contrast, avoided chances to make friends in new situations and to stand out academically or socially in school. By young adulthood, these kids had no clue how to influence or lead others.

For the remaining 82 percent of the Dunedin youngsters, the researchers found only weak links between age 3 temperament — say, being outgoing and confident or reserved but willing to interact with others — and personality 15 years later. In those cases, kids were able to connect with adults and peers throughout childhood regardless of temperament.

Later in life, the undercontrolled 3-year-olds faced the worst prospects. Those individuals had volatile, unstable relationships with family, friends, romantic partners and coworkers by age 21; males in that group were especially likely to develop gambling problems by age 32.

Other findings from the three studies cover a lot of ground. Consider the following: Good or bad parenting predicts how girls, but not boys, will relate as adults to their own 3-year-olds. Regular marijuana use starting in the teen years harms mental health far more than physical health. As physical abuse and other childhood adversities add up, individuals become more likely to suffer a rapid decline in many markers of biological age — including immune, kidney and heart function — by their 20s and to suffer from poor health by age 38.

Refreshingly, the authors acknowledge that the science of human development is not advanced enough to make pronouncements about how to raise children. Disappointingly, the authors offer few peeks at their personal backgrounds and how they ended up doing what they do. Despite that gap, and the inability of these findings to address development in non-Western cultures, after finishing the book, I couldn't help but wonder what will happen as these people, tracked since childhood, enter the second half of their lives. — Bruce Bower



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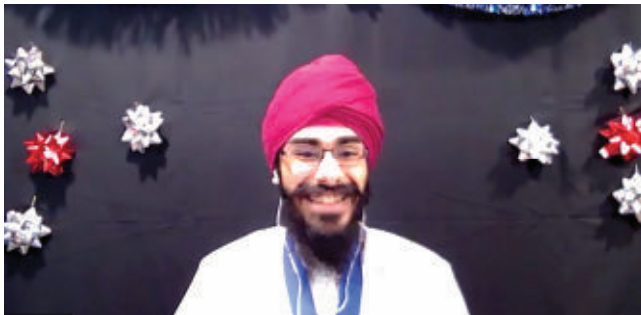


# Teen scientists win \$1.8M at Virtual Regeneron Science Talent Search

Society for Science & the Public and Regeneron announced the top winners of the Regeneron Science Talent Search, the nation's oldest and most prestigious science and math competition for high school seniors. For the first time in its history, the competition took place virtually, in order to keep finalists and their families safe during the ongoing coronavirus pandemic. The Regeneron Science Talent Search provides a national stage for the best and brightest young minds to present their original research ideas to leading scientists.



**Lillian Kay Petersen**, 17, of Los Alamos, N.M., won the \$250,000 top award. She invented a simple tool for predicting harvests early in the growing season, which helps to improve food distribution planning and offers a promising resource to those working to address global food insecurity.



Second place and \$175,000 went to **Jagdeep Bhatia**, 18, of Green Brook, N.J., for developing two fast and simple machine learning algorithms for computer programs that are attempting to learn new concepts under the tutelage of an instructor, either a computer or a human.



Third place and \$150,000 went to **Brendan Crotty**, 18, of Muskogee, Okla., for his project where he designed and built an efficient hybrid gas burner that could help reduce the ecological impact of industries like power generation and materials manufacturing.



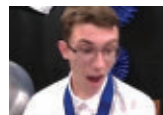
Fourth Place:  
**Rupert Li** of Portland, Ore., received a \$100,000 award.



Fifth Place:  
**Anaiah Thomas** of Teaneck, N.J., received a \$90,000 award.



Sixth Place:  
**Katherine St. George** of Merrick, N.Y., received an \$80,000 award.



Seventh Place:  
**Alek Westover** of Belmont, Mass., received a \$70,000 award.



Eighth Place:  
**Adriane Thompson** of Westerville, Ohio, received a \$60,000 award.



Ninth Place:  
**Rohan Wagh** of Portland, Ore., received a \$50,000 award.



Tenth Place:  
**Arjun Neervannan** of Irvine, Calif., received a \$40,000 award.





AUGUST 1, 2020

### Probing the sun

Neutrinos produced in the sun’s core could shed light on how much of the sun is composed of elements heavier than helium, **Emily Conover** reported in “Elusive class of neutrinos spotted” (SN: 8/1/20, p. 11). Reader **Simon Read** was curious about other ways physicists could study the sun. He suggested gravitational waves might be a good way to study the sun’s massive eddies.

In general, just about any accelerating massive object can produce the space-time ripples known as gravitational waves, but most are too tiny to detect. That’s probably the case for gravitational waves from the churning of the sun, **Conover** says, “otherwise we would have seen them already.”

There’s more that goes into the formation and detection of gravitational waves than just an object’s mass. “For example, the object’s acceleration has to be large enough and the waves emitted have to match the frequency of gravitational waves that experiments can detect,” **Conover** says. Scientists typically detect gravitational waves from black holes that orbit around one another before colliding and merging into one. Solar eddies have much less mass, and the mass moves more slowly.

Additionally, to produce gravitational waves, the accelerating mass must be asymmetrical. “A perfectly spherical, spinning object would produce no gravitational waves no matter how fast you spin it and how massive it is,” **Conover** says. “In black hole collisions, you have big black holes circling each other, separated by empty space in between.” Swirling solar material wouldn’t be as asymmetric as the black hole scenario, so would likely produce smaller waves.

Black hole systems are relatively easy to understand theoretically: Black holes are all identical to one another aside from mass and spin. “That means it’s possible to calculate the gravitational waves you’d expect from a given pair, which is how physicists know what to look for,” **Conover** says. “That would be hard to do with the chaotic churning of the sun.”

### Electrifying science

Two extreme lightning bolts, called megaflashes, more than doubled previous records, **Carolyn Gramling** reported in “A pair of lightning bolts zap the competition for lengthiest bolts” (SN: 8/1/20, p. 5). Reader **Lucille Cholerton** wondered why megaflashes occur.

Megaflashes form within vast networks of thunderstorms and cloud cover called mesoscale convective systems. Within these systems can be broad swaths of steady rainfall called stratiform regions, **Gramling** says. Such regions have less lightning activity than other parts of mesoscale convective systems, which allows charges to build up in the clouds over very long distances. A spark, perhaps a flash of lightning from elsewhere, can trigger a cascade of electric discharges within a stratiform region, creating a megaflash.

### Shoring up mussels

Biologists are on a mission to save a freshwater mussel from extinction, **Stephen Ornes** reported in “The golden riffleshell’s Appalachian road trip” (SN: 8/1/20, p. 22). “Getting readers to be concerned about survival [of] rhinos and tigers is simpler than the challenge that author Stephen Ornes sets and meets: making us care about these dinky invertebrates,” reader **Guy Webster** wrote. “He gives us scene-setting stories with human heroes, mixed with important information about the freshwater mussels,” **Webster** wrote. “Thanks for publishing stories like this.”



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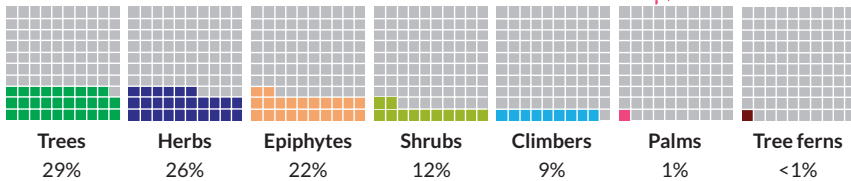
## New Guinea's flora stuns in new inventory

Not only is New Guinea home to feathered marvels like birds of paradise, but the island is also brimming with foliage. Now the first verified count of the island's flora reveals that New Guinea hosts more than 13,600 vascular plant species — trees, shrubs and other plants that have specialized tissue to transport nutrients.

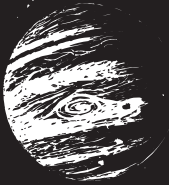
The inventory shows that New Guinea, which includes Papua New Guinea and the Indonesian part of the island, has the highest known plant diversity of any island, researchers report August 5 in *Nature*.

From *Syzygium* flowers that resemble sea anemones to *Bulbophyllum* orchids with spiderlike appendages, New Guinea is filled with astounding examples of botanical specimens (a selection are shown). “This region is really just amazing,” says Rodrigo Cámara Leret, a botanist at the University of Zurich.

Cámara Leret and 98 other researchers identified nearly 705,000 plant specimens from New Guinea. Most were trees, which made up 29 percent of species, closely followed by herbs and plants known as epiphytes that grow on other plants. Shrubs, climbing plants, palms and tree ferns rounded out the rest. (In the illustration at left, each grid box represents 1 percent of species.) — *Erin Garcia de Jesus*



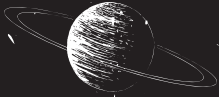
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