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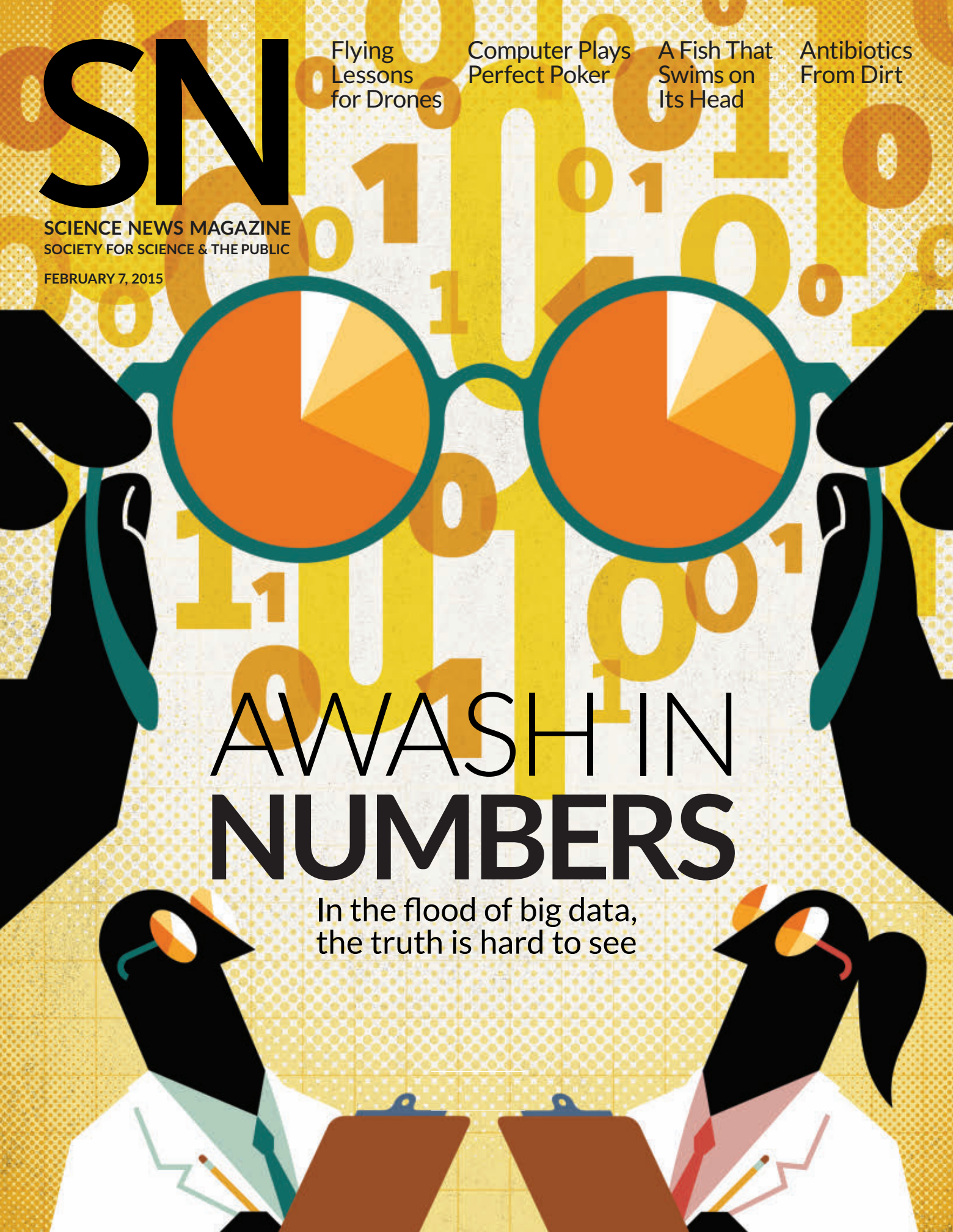
FEBRUARY 7, 2015

Flying Lessons for Drones

Computer Plays Perfect Poker

A Fish That Swims on Its Head

Antibiotics From Dirt



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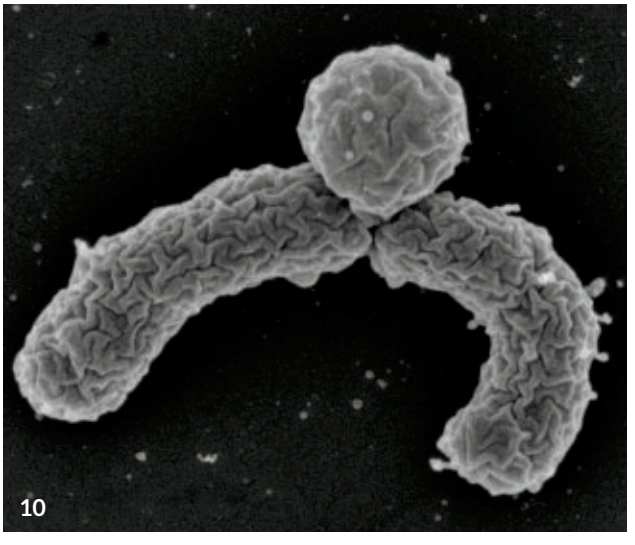
ScienceNews

Features

News



Departments

COVER When researchers analyze massive datasets, the challenge of getting results that can be replicated comes into focus. *James Provost*

CLOCKWISE FROM TOP LEFT: JAMES PROVOST; COURTESY OF ANNA MCVEY; WILLIAM FOWLE/NORTHEASTERN UNIV.

Contemplating the coming of the drones

Biologist Ty Hedrick films the aerial gymnastics of cliff swallows and other acrobatic fliers. His studies, as freelance writer Nsikan Akpan describes on Page 18, reveal the wonders that some avian standouts are capable of — from handling more than 7 g's on a sharp turn to soaring at speeds up to 56.2 kilometers per hour. Interesting in its own right, this research also has a practical side. As Akpan reports, studies of animals aloft inform the effort to design next-generation drones capable of doing as birds do — landing on a wire without stalling or navigating a tree-filled forest without crashing. These smart drones would be autonomous flying robots, equipped with sophisticated computers, able to sense and analyze information independent of their human controllers.

Perhaps most startling is the statement that by 2030 the Federal Aviation Administration expects as many as 30,000 drones to regularly cruise U.S. skies. In January, the *New York Times* announced it was working with other media outlets and scientists at Virginia Tech to look into the use of drones for journalism. You can imagine the paparazzi co-opting them next, flying into celebrities' backyard barbecues (if they haven't already). A colleague of mine said that he would like to buy a drone to check if the gutters on his house need cleaning.

It seems that these mechanical fliers, and not an army of humanoid machines, may represent the robotic future. And it's close by. Tiny spy planes and backyard toy fliers are already here. Package-carrying mini-copters are in development. But some of the uses are not so benign. Smart missiles that can select and kill targets raise serious ethical concerns. Key to the debut of these sophisticated drones are advances in artificial intelligence, which is already used in medical diagnostics, high-speed stock trading, Google's driverless car and, as Andrew Grant reports on Page 14, to "solve" poker, besting any human at Texas Hold'em.

The science behind the development of better fliers, or smarter ones, is fascinating stuff. But it's also important sometimes to stop and consider the implications of the technologies that science begets. I can't help but find the prospect of a sky full of drones a bit unsettling, however beautiful their flight. — *Eva Emerson, Editor in Chief*

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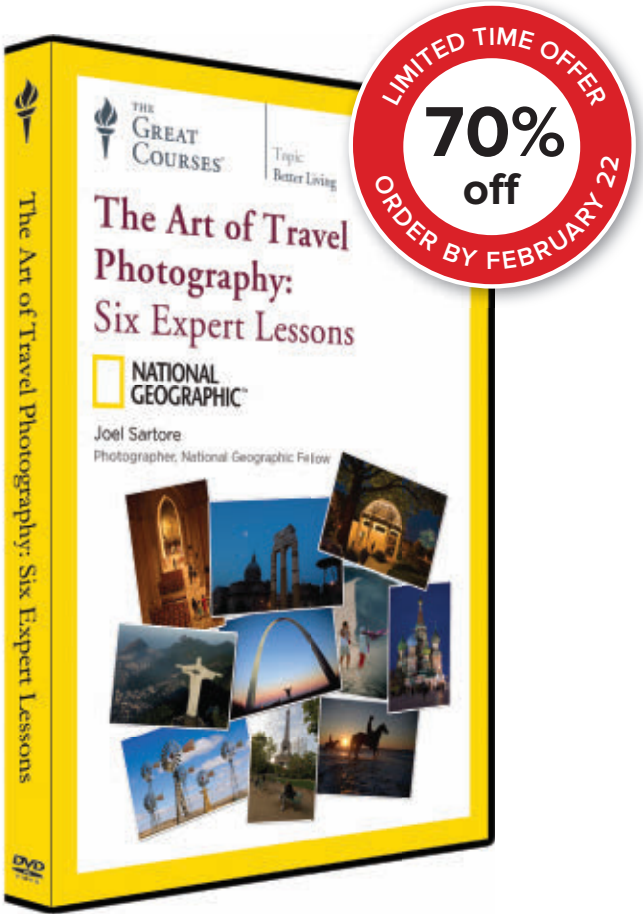

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ABOUT YOUR PROFESSOR

Joel Sartore is a professional photographer and a regular contributor to National Geographic magazine. His assignments have taken him to some of the world's most beautiful and challenging environments and have brought him face to face with a diversity of wildlife in all 50 U. S. states and all seven continents. He was recently named a National Geographic Fellow for his work on "The Photo Ark," a multiyear project to document the world's biodiversity in studio portraits. His photograph of a lion in a tree was voted the best picture by National Geographic magazine in 2011.

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Excerpt from the February 6, 1965, issue of *Science News Letter*

50 YEARS AGO

Mercury flyby proposed

An unmanned space probe that would pass 1,100 miles from Venus and then come within 4,700 miles of Mercury has been proposed. Planned for launching in late July or August of 1970, the spacecraft would need less than a third as much thrust as one going directly to Mercury without visiting Venus.... Neither NASA nor JPL are as yet planning such a mission as this, but the techniques involved are applicable to other multi-planet flights.

UPDATE: Mariner 10 launched in 1973 and the next year became the first probe to visit Mercury and the first to use the gravity of another planet — Venus — to help it on its way. Images revealed a barren terrain riddled with craters. No spacecraft visited again until MESSENGER, which in 2013 completed the maps begun nearly 40 years earlier (*SN: 1/12/13, p. 17*). Now out of fuel, that mission will end this spring, when the probe crashes into Mercury's surface.

Speckled shrimpfish occasionally pull up their snouts, but vertical is their preferred swimming posture.

IT'S ALIVE

That's how shrimpfish roll

Shrimpfish swim forward standing on their heads. And that puts a rare spin on fishy turns.

Long, skinny *Aeoliscus punctulatus* mostly hang tails-up in the water with their mouths probing the seabed. But they aren't just holding a pose, as upended trumpet fish do when hiding among sea grasses. The shrimpfish do most of their swimming horizontally in their vertical stance, sliding along the sand like pens in invisible hands.

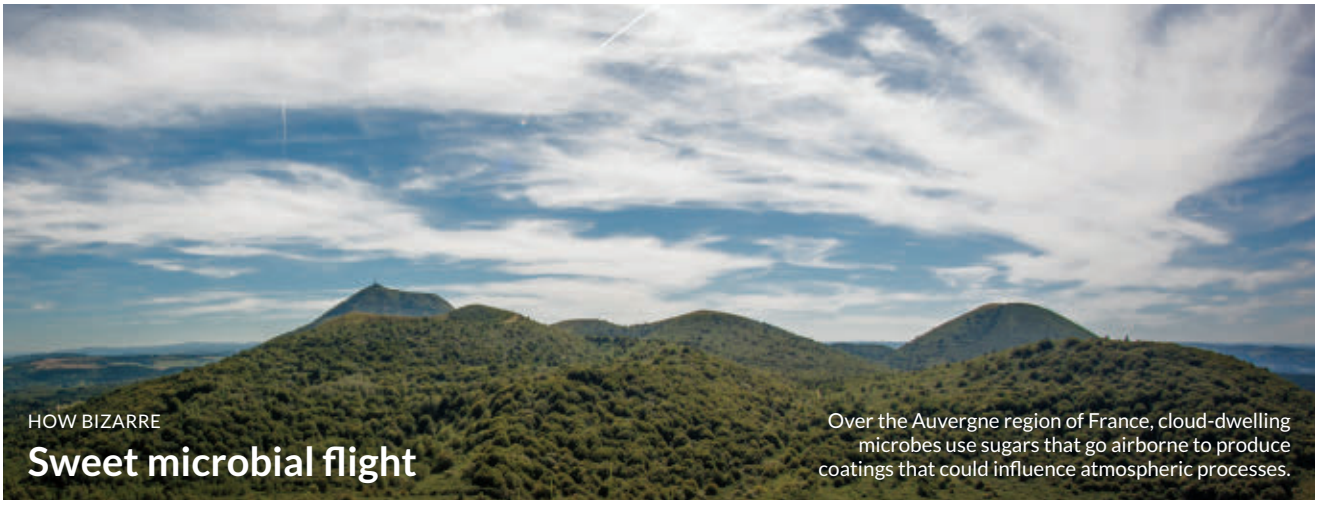
"They're absolutely bizarre fish," says Frank Fish of West Chester University in Pennsylvania, who studies animals' aquatic motions. A tank of shrimpfish caught his eye at a public aquarium in Eilat, Israel, near where he was on sabbatical in 2014. He and Roi Holzman of Tel Aviv University set up high-powered lights to take detailed video of the fish moves, becoming themselves objects of tourists' curiosity.

Most other fishes in cross section approximate a circle or an oval, Fish says. But a shrimpfish cross section looks more like a slice of an airplane wing. The fish's back, its leading edge as it glides along, is wider and its sides taper toward the belly like a wing's drag-reducing taper. And the usual fin on a fish back has moved over evolutionary time to join the shrimpfish tail and anal fins in a wavering multitool cluster.

As befits a mostly vertical fish, the center of buoyancy has shifted tailward of the center of gravity, Fish and Holzman found. (Imagine swimming with a beach ball — it would be much more stable above than under the mass of a beachgoer.) Because of this alignment, the shrimpfish hangs in the water and turns easily, Fish says. In general, fish don't roll along their long axis, but a turning shrimpfish does. "They do full pirouettes on their heads," Fish says. "I'd like to see a prima ballerina do that." — *Susan Milius*

LAURAD/SHUTTERSTOCK

Watch a video of shrimpfish swimming at **bit.ly/SN_shrimpfish**



HOW BIZARRE

Sweet microbial flight

Over the Auvergne region of France, cloud-dwelling microbes use sugars that go airborne to produce coatings that could influence atmospheric processes.

Floating in a cloud and noshing sweets while wrapped in a cozy bubble sounds like a pleasant dream. For some lucky bacteria, it may be a reality.

Researchers have discovered that a cloud-dwelling microbe, in this case a species of *Bacillus* bacteria, can eat up the sugars floating around in the atmosphere.

The microbes, which the scientists plucked from clouds above the Auvergne region of France, were known to be metabolically active in clouds, but their diets were a mystery.

Back in the lab, Anne-Marie Delort of Blaise Pascal University in Clermont-Ferrand, France, and her team provided a feast of carbohydrates commonly kicked into the atmosphere by earthlings. The bacteria broke down the heavenly sweets and reused the molecular rubble as building blocks for protective polysaccharide coatings.

Those coatings, which may shield cloud-living microbes from ultraviolet radiation and frigid temperatures, may also spur droplet formation in clouds, which could alter atmospheric processes, the researchers report November 12 in *Environmental Science & Technology*. — *Beth Mole*

20
percent
Approximate fraction of small particles that are actually bacteria in high-altitude clouds

SOURCE: N. DELEON-RODRIGUEZ *ET AL*/ *PNAS* 2013

A gustometer drips precise quantities of colored liquids into the mouth of a woman lying in a brain scanner.

SAY WHAT?

Gustometer \guhs-TOH-meh-ter\ n.

A device used to squirt measured amounts of liquids into the mouth of a person in a taste study. Researchers often pair the instrument with brain scanning technology.

Recently, a study of wine tasting pitted 10 of the top sommeliers from France and Switzerland against 10 novices. Researchers led by Lionel Pazart of Besançon University Hospital in France custom-built a gustometer to conduct the blind taste test. The scientists compared how brain activity changed when people tasted chardonnay, pinot noir or water.

When sipping wine, the experts had greater activity in several parts of their brains, including regions involved in memory, than novices did, the researchers report in October in *Frontiers in Behavioral Neuroscience*.

Sommeliers' expertise may allow them to process sensory input about a wine — its taste and bouquet — while simultaneously recalling other information, such as the reputation of the winery that produced the beverage.
— *Tina Hesman Saey*

FROM TOP: PROUDLY VEGAN/FLICKR (CC BY-NC-SA 2.0); FRANK POOLE

BODY & BRAIN

Oxygen may raise lung cancer risk

Incidence drops at higher elevations, where air is thin

BY TINA HESMAN SAEY

Breathing at sea level may be hazardous to your health, a new study hints. Comparing cancer rates for people living at various elevations found that lung cancer rates are lower at high elevations, where the air is thinner.

If every person in the United States lived at elevations above 3,400 meters, such as atop Mount Hood in Oregon, there would be about 65,000 fewer cases of lung cancer each year, researchers Kamen Simeonov and Daniel Himmelstein estimate. (In 2014, an estimated 224,210 new cases of lung cancer were expected in the United States.) The findings could mean that lung cancer is linked to altitude — more specifically to the amount of oxygen in the air, the researchers report online January 13 in *PeerJ*. Other cancers included in the study weren't linked to altitude.

Simeonov and Himmelstein are not the first to note the health benefits of high-altitude living, says Paul Hwang, a physician and scientist at the National Heart, Lung and Blood Institute in Bethesda, Md. Oxygen can form molecules that damage cells and lead to cancer. Hwang and colleagues have demonstrated that reducing oxygen levels could prolong the lives of mice prone to cancer.

The finding presents a conundrum, though, because people must breathe oxygen to live. "Life is hazardous," Hwang quips.

The study is "quite provocative," says cancer epidemiologist Elizabeth Platz of Johns Hopkins Bloomberg School of Public Health, and it is a clever analysis of publicly available data. However, anyone hoping to avoid lung cancer would do far better to not smoke than to pack their bags and move to the mountains, she says.

> "We're not suggesting that everyone should be moving" to higher altitudes.
>
> KAMEN SIMEONOV

Simeonov, now a medical and graduate student at the University of Pennsylvania, got the idea that elevation might be linked to lung cancer when he noticed that people in Austria have some of the highest smoking rates in Europe, but relatively low lung cancer rates. He discussed the hypothesis with his roommate, Himmelstein, who is now a bioinformatics graduate student at the University of California, San Francisco.

In their spare time, the two researchers gathered and analyzed information from government databases, focusing their attention on 260 counties in the western United States. Those locations vary in elevation from Imperial County, Calif., at 11 meters below sea level, to San Juan County, Colo., at 3,473 meters above sea level. As elevation increases from the lowest county to the highest, the concentration of oxygen in the atmosphere drops by 34.9 percent.

For every thousand meters of altitude gained, lung cancer incidence dropped by 12.7 percent, the researchers found. The rates of nonrespiratory cancers such as breast, prostate and colorectal cancers did not show a link to elevation.

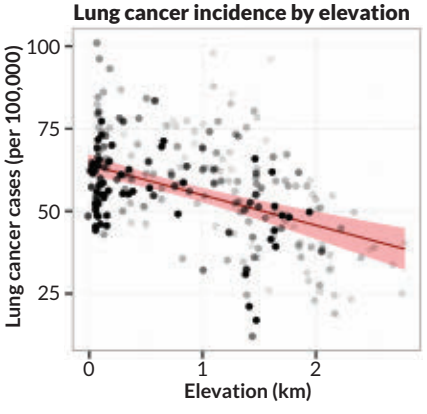
Simeonov and Himmelstein took into account factors, some of which have been linked to cancer, that change along with elevation — radon levels, climate and exposure to ultraviolet light and fine particle pollution. But none of those factors explained the drop in lung cancer rates as well as elevation did.

The most likely culprit for the elevation and cancer link is oxygen, they say. However, studies such as this one can only suggest relationships between environmental factors and health. "We can't say that it's oxygen" for sure, Simeonov says. All that the researchers can determine is that increasing elevation seems to protect against getting lung cancer. "This is an interesting observation and an interesting finding that needs to be explored mechanistically," Simeonov says. "We're not suggesting that everyone should be moving" to higher altitudes.

Hwang says he was a "little surprised" that only lung cancer was related to altitude. That link makes sense because the lungs are directly exposed to atmospheric oxygen. But other internal organs are also constantly bathed in oxygen-rich blood, with oxygen concentration directly related to the levels in the outside air. Each type of cancer may react differently to the effects of high oxygen levels, Hwang says.

Paradoxically, previous research has shown that low oxygen concentrations can spur cancer growth, Hwang points out. The contradiction might be resolved by considering how cancer gets started. Hwang thinks that low oxygen levels may prevent DNA damage that initiates a tumor. But once a tumor starts to grow, oxygen starvation may fuel its growth.

Like all epidemiological studies, this one suffers from the caveat that the connection could be coincidental, Platz says. The researchers need data on the diet, lifestyle, smoking habits and health of individuals to make the link tighter. "I'm not saying they are wrong," Platz says. "I'm just saying they can't rule out those other confounding factors." ■



Up high Lung cancer risk falls as elevation increases. Dots represent U.S. counties; darker dots indicate counties with larger populations. SOURCE: K.P. SIMEONOV AND D.S. HIMMELSTEIN/*PEERJ* 2015

ATOM & COSMOS

Life might like cool stars' rocky planets

Atmospheric heating could evade tidal locking, aid habitability

BY CHRISTOPHER CROCKETT

Small, rocky planets (one illustrated here) around cool, red stars might be more hospitable to life than previously suspected.

There may be more Earth-like environments in the universe than previously thought. Warm, rocky planets that orbit close to their stars might not end up with one side in perpetual daylight as suspected, allowing such planets to sustain an environment hospitable to life.

For the first time, researchers have shown that the gentle tug of a star's gravity on a thin atmosphere can keep a planet spinning even when other forces threaten to slow it down. While planetary scientists have long suspected that this process keeps Venus slowly turning, the mechanism could also work on a planet without Venus' massive atmosphere, Jérémy Leconte, an astrophysicist at the University of Toronto, and colleagues report online January 15 in *Science*.

Most stars in the galaxy are M dwarfs, red stars that are smaller and dimmer than the sun. Because these stars are relatively cool, their habitable zones — the region around a star where liquid water could, in principle, survive on a planet's surface — are narrow. Planets have to huddle up close to the star to stay warm. For planets so close, the star's gravity slows down their spin so that one side always faces the star, a circumstance known as tidal locking. Climate on a locked planet might be too harsh for life. Dayside warmth could blow ferocious winds; all the water might be ice on the nightside.

Leconte and colleagues used computer simulations to determine that heat in a planet's atmosphere may prevent tidal locking. Heat at a planet's equator drives winds that push air toward the nightside. When the star pulls on the atmosphere, it tugs a little more on the side with more mass, which gradually causes the planet to spin faster. If Earth were as close to the sun as Venus, the researchers found, these subtle nudges would make our days shorter and shorter. "It's quite impressive," Leconte says, "that the atmosphere ... can spin up the whole planet."

At the Earth's actual distance from the sun, the effect of these atmospheric forces is negligible. But on an Earth-sized world in the habitable zone of an M dwarf, the relentless tug on the atmosphere could be enough to keep the planet spinning, the researchers found.

These results should stimulate a lot of research, says Edwin Kite, a planetary scientist at the University of Chicago. "It's reasonable, though not proven," Kite says, "that most habitable-zone planets orbit M dwarfs." Because M dwarfs outnumber other stars near the sun, that's where the closest habitable planets are likely to be found. The James Webb Space Telescope, scheduled to launch in 2018, could be able to detect the atmospheres of rocky worlds around M dwarfs and test ideas about their habitability. ■

MATTER & ENERGY

Graphene's allure can be magnetic

Proximity allows carbon sheet to borrow a material's power

BY ANDREW GRANT

Although atom-thick sheets of carbon called graphene have many extraordinary properties, magnetism isn't one of them. But a new study reveals that graphene can simply borrow the magnetic properties of a nearby material.

The technique, reported in the Jan. 9 *Physical Review Letters*, creates a magnetic form of graphene by precisely placing it above a magnetic, insulating compound. It's the first time researchers have magnetized graphene while also preserving the ultrathin material's other tantalizing properties, such as the superspeed of electrons coursing through it.

Graphene, discovered in 2004, is valued for its promise in electronics. Its electrons move much faster than those in silicon semiconductors. But it does not exhibit magnetism, which would be useful for certain technological applications.

Yafis Barlas, a theoretical physicist at the University of California, Riverside, and colleagues wondered whether the magnetic compound yttrium iron garnet placed close to graphene would share its magnetism while leaving the carbon sheet's structure and electronic properties intact. To maximize contact between materials, the researchers laid the graphene atop an extremely smooth sample of the yttrium iron garnet, an electric insulator that doesn't interfere with the graphene's electron flow.

The researchers confirmed that the graphene was magnetized by exposing it to an external magnetic field. In nonmagnetic conducting materials, electrical resistance in the direction perpendicular to the current rises steadily as the sample is exposed to a strengthening field. But the resistance in the graphene jumped disproportionately to the strength of the field. This phenomenon, known as the anomalous Hall effect, indicated that the graphene was ferromagnetic, the type of magnetism exhibited by iron and yttrium iron garnet. "The graphene just borrows the magnetic properties," says Allan MacDonald, a condensed matter physicist at the University of Texas at Austin.

He also points out that graphene is not the only promising ultrathin material. He wonders whether the same technique could magnetize a sheet of molybdenum disulfide, a material whose electronic properties resemble those of silicon. ■

D. AGUILAR/HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS

When flying over the Himalayas, bar-headed geese change their altitude to match the topography.

LIFE & EVOLUTION

Migration is a roller coaster for bar-headed geese

Adjusting altitude over the Himalayas is less effort for birds than steadily flying high

BY KATE BAGGALEY

Bar-headed geese rise and fall with the terrain below them when they migrate, researchers report in the Jan. 16 *Science*.

This roller coaster flight pattern saves the birds energy. Flying along a strictly straight path in high altitudes is more work than staying low to the ground with occasional climbs, the scientists concluded after tracking altitude, wingbeats and heartbeats in bar-headed geese (*Anser indicus*) migrating over the Himalayas and Tibet. Updrafts may help the birds recover some of the altitude they lose with each dip in the topography.

The findings are a surprise, says comparative physiologist Steven Portugal of Royal Holloway, University of London. "Geese are not renowned for flight maneuverability or sophistication."

To understand the geese's high-altitude journey, scientists had focused on the birds' adaptations to low-oxygen conditions. With altitude, air becomes less dense. At an elevation of 5,500 meters, the air contains half as much oxygen as at sea level. Bar-headed geese have higher lung capacities than other geese and more blood vessels in the flight and heart muscles, which allow the birds to reach altitudes of over 7,000 meters.

"Before, the understanding was that the real challenge is the oxygen concentration," says Gil Bohrer, an environmental engineer at Ohio State University. "Not enough attention was paid to the physical challenge of flight in thin air."

As the birds migrated from Mongolia to India, tiny data loggers implanted in their abdomens recorded atmospheric pressure to monitor the birds' altitude. The instruments also recorded the birds' heart rates and how their bodies moved in response to each flap of the wings, indicating the rate at which their wings were beating.

The researchers used GPS coordinates from a previous study to compare the birds' dips and climbs in altitude with the topography of the land.

The birds typically stayed within 100 meters of the ground, dipping whenever the terrain dropped and rising when it became higher. "They regularly throw away this altitude that they just worked hard to get," says study coauthor Charles Bishop.

Flying to lower altitudes appears to be worth the loss. As the birds climb higher and the air thins, they have to beat their wings faster to get the airflow they need to generate lift and thrust, says Bishop, a zoologist at Bangor University in Wales. These wingbeat adjustments are more energetically expensive than scientists had expected. A 5 percent increase in wingbeat frequency translated to a 19 percent boost in heart rate and a 41 percent rise in oxygen consumption. "Small changes in wing motion are costing them a lot of energy," says Bishop. "The roller coaster strategy is actually the energetically best strategy."

At lower altitudes, the geese are less likely to be buffeted by strong winds. In a few cases, the researchers noticed that the birds would ascend very quickly without a corresponding increase in their heart rate. This indicated that the birds were taking advantage of strong updrafts. The researchers also speculate that flying low allows the birds to use gentler updrafts that dissipate with height.

"We know they're well-adapted to high flights," says Bishop. But "just because they're capable doesn't mean they're doing it all the time.... Their lives are more complicated than that."

Portugal says he would have liked the research to address whether flying closer to the ground comes with its own risks. "Does it bring them into closer range for aerial attacks from birds of prey?" he asks. ■

A researcher in Mongolia rounds up bar-headed geese to fit them with data loggers.

FROM TOP: NYAMBAYAR BATBAYAR; BRUCE MOFFAT PHOTOGRAPHY

ATOM & COSMOS

Kepler finds 554 potential planets

Data dive adds eight worlds that might be able to host life

BY CHRISTOPHER CROCKETT

The Kepler space telescope has added 554 planet candidates to the growing list of worlds beyond the solar system, astronomers announced January 6. In addition, Kepler researchers have confirmed another eight worlds with the potential for hosting liquid water.

The data bring Kepler's total number of planet candidates to 4,175, including more than 800 with diameters roughly the size of Earth's. Among these far-off locales are a few worlds that might not be too different from home.

"These are the closest analogs to the Earth-sun system to date," said Fergal Mullally, an astronomer at NASA's Ames Research Center in Moffett Field, Calif. One such candidate is roughly 1.3 times as wide as Earth and takes just over a year to orbit a star with a temperature similar to the sun's. The planet orbits within the star's habitable zone, where temperatures may allow for liquid water.

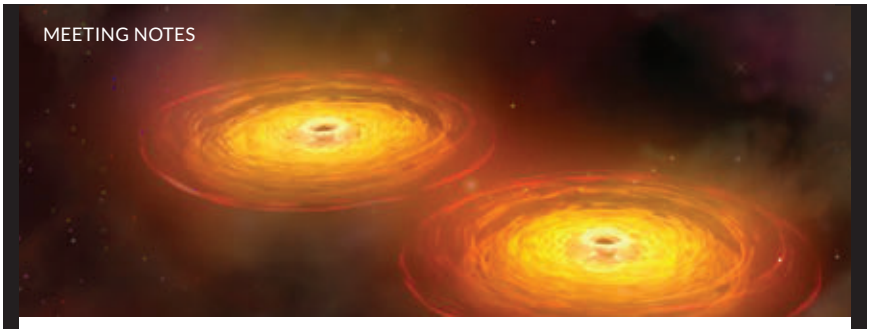
Researchers found the new candidates while analyzing Kepler's final year of data. From 2009 to 2013, the planet hunter stared at more than 150,000 stars in the constellations Cygnus and Lyra, looking for the silhouettes of planets passing, or transiting, in front of their host stars (*SN: 12/27/14, p. 20*). Until now, Kepler had predominantly found planets with relatively short orbits, worlds that have transited often enough to be considered likely candidates. With the additional year of data, researchers can finally build a convincing case for Earth-sized planets in the habitable zones around sunlike stars, where transits may happen only once a year.

Mullally cautioned that scientists still have to verify whether all the possible planets are, in fact, planets. Kepler sees planets as periodic dips in starlight as they pass between their stars and the telescope. But companion stars and other phenomena can mimic this signature. Ideally, astronomers would turn to ground-based telescopes to confirm the detections by looking for tiny wobbles in the host stars caused by the planets' gravitational tugs. But many of these worlds are too small and too far from their stars for such wobbles to be detectable. Instead, researchers will have to calculate how likely each detection is to be a real world.

Researchers applied such calculations to the first three years of data and have verified that eight previous candidate planets may be in their stars' habitable zones. That brings the number of confirmed worlds with the potential conditions for life to 13. Two of these worlds are rocky planets not much bigger than Earth. Each orbits a faint star that is much cooler than the sun.

"Kepler's done an amazing job," said Joshua Pepper, an astronomer at Lehigh University in Bethlehem, Pa. Not only has the telescope turned up Earth-sized, possibly habitable planets, he said, but it's also revealed a lot about the variety of planetary systems. Knowing what types of stars host planets and how those planets are arranged will help future missions choose where to look for more planets. ■

MEETING NOTES



A. HOBART/CXC/NASA, JOSH BARNES/UNIV. OF HAWAII, JOHN HIBBARD/NRAO

Pair of black holes get ready to take the plunge

Two black holes (illustrated above) are preparing to face off in the center of a distant galaxy. The black holes are closer to each other than any other known black hole duo, providing a peek at the final stages of a possible collision.

The black holes live roughly 3.7 billion light-years away in a quasar, the ferociously bright core of a galaxy lit up by superheated gas spiraling into a supermassive black hole. Quasars typically vary in brightness randomly. But the light from this quasar varied with a steady period over the last two decades, suggesting that black holes are working together, S. George Djorgovski of Caltech reported January 7. The work also appeared online January 7 in *Nature*.

Separated by a few hundredths of a light-year, the black holes may merge in roughly 1 million years. Close black hole pairs are thought to be relatively common but are hard to find because they're so far away. — *Christopher Crockett*

Large rocky planets excel at building oceans

The best oceanfront real estate in the galaxy may be on a planet two to four times as massive as Earth. Such super-Earths steadily grow oceans for billions of years whereas less massive planets deplete their seas relatively quickly, researchers reported January 5.

Laura Schaefer of the Harvard-Smithsonian Center for Astrophysics used computer simulations to study how the mass of a planet affects its water cycle. Small planets build oceans quickly but can't sustain their water cycle, in which plate tectonics draws water into the mantle and volcanoes return it to the atmosphere. Such a planet's water eventually becomes trapped in the mantle. Inside super-Earths, however, high pressure can keep the water cycle running for at least 10 billion years. — *Christopher Crockett*

BODY & BRAIN

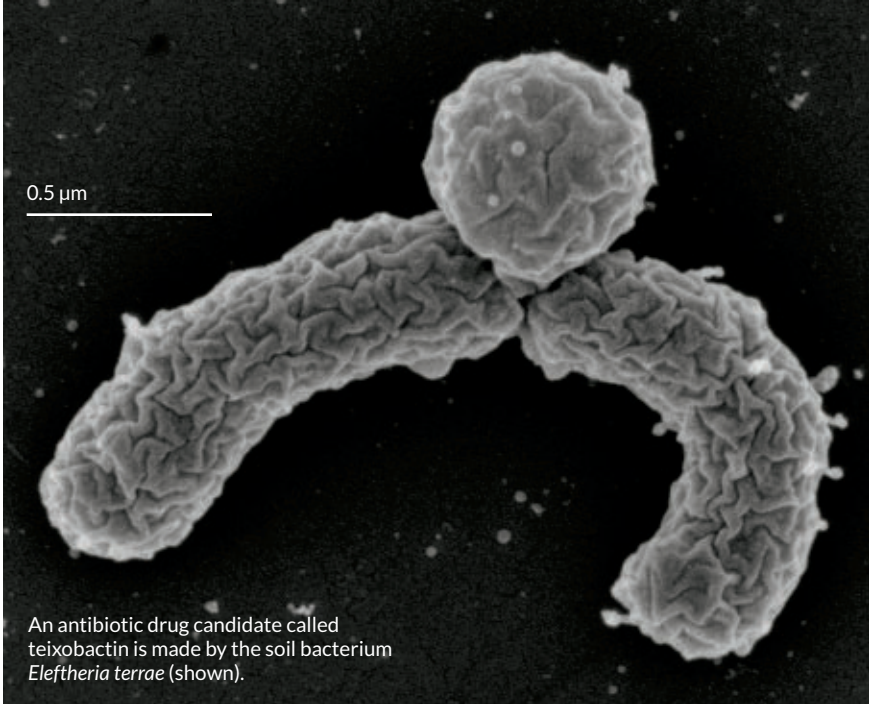
New antibiotic shows promise

In lab tests, bacteria did not gain resistance to compound

BY NATHAN SEPPA

A compound isolated from soil might have the right stuff for fighting troublesome bacteria, researchers report online January 7 in *Nature*. While still far from being declared a true antibiotic drug, the compound teixobactin tested well in lab dishes against *Clostridium difficile*, a microbe high on doctors' most-wanted list, as well as against bacteria that cause anthrax and tuberculosis.

In mice, teixobactin also knocked out strep microbes without showing any adverse effects. And it killed staph bacteria that were resistant to other drugs. In these tests, the target bacteria showed no hint of developing resistance to teixobactin itself. That's important because too often bacterial mutations engender resistance to treatment, rendering many drugs ineffective and outpacing Big Pharma's efforts to come up with alternative drugs.



An antibiotic drug candidate called teixobactin is made by the soil bacterium *Eleftheria terrae* (shown).

Teixobactin works by interrupting the biosynthesis of the building blocks that bacteria need to construct their cell walls, says study coauthor Kim Lewis, a biochemist at Northeastern University in Boston. The breakdown of the cell wall destroys the bacteria's structure. The new compound's lethality is directed at one broad class of microbes called gram-positive bacteria. It is not effective against some microbes, such as *E. coli*, a gram-negative bacterium.

The oft-prescribed antibiotic vancomycin also attacks cell wall biosynthesis. Microbes needed about 35 years — a long time in the world of bacteria — to gin up resistance to that drug, notes Gerard Wright, a biochemist at McMaster University in Hamilton, Ontario, who was not involved in the study. "In a field dominated by doom and gloom," he writes in a commentary in *Nature*, the new finding "offers hope that innovation and creativity can combine to solve the antibiotics crisis."

Researchers are excited about the finding in part because the method by which they discovered teixobactin might yield other drug candidates. Bacteria in

MATTER & ENERGY

Retraction imminent for brute-force chemistry research

Paper on ripping apart ring-shaped molecules to be withdrawn, but method works nevertheless

BY BETH MOLE

After an investigation identified scientific misconduct, a study that reported a way to reverse a powerful chemical reaction will soon be retracted. Yet, despite dubious data, chemists say the study's method works.

The study, published in *Science* in 2011, found that simple mechanical force could undo chemical reactions that form sturdy molecular ring structures called triazoles (*SN: 12/31/11, p. 24*; *SN Online: 9/15/11*). The study's leader, Christopher Bielawski, then a professor at the University of Texas at Austin, says he notified university officials as soon as he became aware of the potential misconduct. Bielawski has since moved to the Ulsan National Institute of Science and Technology in South Korea.

Last June, *Science* published an expression of concern about the study, flagging questionable data and referencing an ongoing investigation by the University of Texas. Similar expressions of concern were published for at least seven other studies from Bielawski's lab and another study has been retracted.

The investigation recently ended and found misconduct. "One author of several papers in question told UT officials that he or she — acting alone — had falsified and otherwise misrepresented data or figures in the papers," says Gary Susswein, a university spokesperson. Susswein cites federal privacy laws to explain why the identity of the guilty scientist and other information have not been revealed.

A spokesperson for *Science*, Natasha Pinol, released a statement on behalf of executive editor Monica Bradford. "We are in discussion with the University of Texas at Austin in an effort to obtain appropriate, transparent language for a retraction," the statement read. "We hope

WILLIAM FOWLE/NORTHEASTERN UNIV.

soil, where the compound was found, naturally make antibiotics that fend off other bacteria. In the past, scientists have tried culturing such microbes in the lab, but many soil bacteria do not readily grow in culture. In the new study, Lewis and colleagues first identified promising bacteria and then grew them in patches of soil.

After one to two weeks of building a colony of desirable bacteria, the team successfully transferred the operation to lab dishes. A microbe called *Eleftheria terrae* makes teixobactin.

Teixobactin will require up to two years of additional testing before it can reach human trials, probably as an injected drug. Tests in people will then take a few more years, Lewis says.

But he is optimistic. "Teixobactin will represent a new class of antibiotics," he predicts. "This represents something of a paradigm shift in our minds because we thought resistance was inevitable." He says bacteria usually gain resistance to a drug through modification of the molecules targeted by those drugs, but the building block bound by teixobactin doesn't lend itself to that. "It would take so much energy for the cell to modify this motif that I think it's unlikely that resistance will appear that way," he says. ■

to publish the retraction early in 2015."

Despite the looming retraction, chemists say that the ring-breaking method described in the 2011 paper and other findings from Bielawski's lab have held up. Materials chemist Jeffrey Moore of the University of Illinois at Urbana-Champaign says that his team has reproduced the lab's findings, as have other researchers. "At least qualitatively," Moore says, "the observations have been validated and the results are correct."

Chemist Andrew Boydston of the University of Washington in Seattle has also validated an experiment similar to the one in the 2011 study. "It is important that researchers ... continue to study these systems," Boydston says. "The literature will work out the details in cases where there are inconsistencies." ■

BODY & BRAIN

Weight-loss surgery may prolong life

Ten years postoperation, mortality rates were nearly cut in half

BY NATHAN SEPPA

Obese adults who undergo weight-loss surgery are more likely to survive the next decade than those who don't. A study in the Jan. 6 *JAMA* finds that, compared with obese people who had no surgery, patients who elected bariatric surgery had mortality rates roughly half as high five and 10 years after the operation.

Earlier research had shown that the surgery can induce weight loss, reverse type 2 diabetes and protect against heart problems (*SN: 9/10/11, p. 26*). Some studies also showed lower mortality rates, but those data largely came from women and young to middle-aged adults.

Nearly three-fourths of the patients in the new analysis were men who were, on average, in their early 50s when they got the surgery. "This gives us evidence that even for older patients there is a survival benefit," and that it extends to men, says Guilherme Campos, a bariatric surgeon at the University of Wisconsin–Madison who wasn't involved in the study.

The researchers used a database of veterans to identify 2,500 men and women who underwent bariatric surgery from 2000 to 2011. The scientists then identified a control group of 7,115 other vets: For each surgical patient, the researchers found roughly three people who matched in age, weight and medical history. People in both groups were very obese at the outset with an average body mass index in the mid-40s. A person with a BMI of 30 or greater is considered obese.

Follow-up ranged up to 14 years. At the five-year point after surgery, 10.4 percent of the people who did not have surgery had died, while only 6.4 percent of those who got surgery had died. At the 10-year mark, the death rate was 23.9 percent among the controls and 13.8 percent in the surgery group.

"It's not a slam dunk that every obese patient should have [bariatric surgery], but every patient should be having a conversation with their doctor," says study coauthor David Arterburn, an internist at the Group Health Research Institute in Seattle.

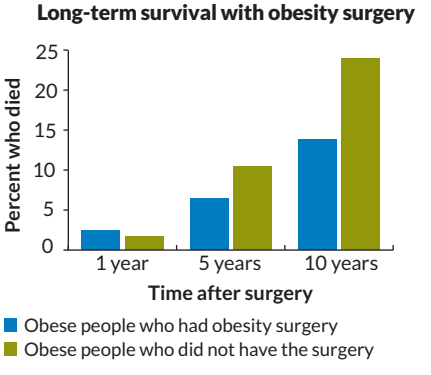
Campos agrees but cautions that people in bariatric surgery studies such as this one aren't randomly assigned to surgery. Randomization is the gold standard for determining the value of medical treatments because it removes self-selection that might skew the findings, warns Campos. Nevertheless, he says, the new data are the best available.

Bariatric surgery speeds up the sensation of feeling full. An individual who gets full faster eats smaller portions and typically consumes fewer calories.

Despite successes, questions remain, Arterburn says. "We still don't know at 10 to 20 years what proportion of patients kept most of the weight off." And it will take years of monitoring to know if there are long-term negative consequences from the surgeries. A 2007 study hinted at increased suicide among surgical patients. Some research suggests alcohol use increases after surgery.

Campos notes that research also finds an increase in accidental death post-surgery. "Maybe these people are out there doing stuff they didn't do before," he says. "Or patients may exchange one addiction for another." ■

Improving the odds People electing to have obesity surgery are less likely to die in the next 10 years than are obese people who don't get the operation. SOURCE: D. ARTERBURN *ET AL*/*JAMA* 2015



A disco clam flashing reflected light off its lips may be warning predators that attempts to bite will not end well.

LIFE & EVOLUTION

Clam flash may ward off predators

Puzzling light display could be chemical-weapons warning

BY SUSAN MILIUS

A disco clam's flashing light show might warn predators of — with no comment on the 1970s — bad taste.

In lab tests, usually voracious mantis shrimp backed off or showed suspiciously little interest in clams as if the flashy flesh was distasteful or toxic, Lindsey Dougherty of the University of California, Berkeley reported January 4. So the antipredator idea is a strong hypothesis among several in the ongoing puzzle of the clam's flashing, said Dougherty.

Ctenoides ales clams put on a steady show not known in any other mollusk. At least once a second, they uncurl the soft lips along the edge of their bodies and reveal embedded silica spheres that reflect a quick streak of ambient light (*SN Online: 6/25/14*). Then the lips curl closed again, hiding the light.

When Dougherty and her colleagues identified the silica reflectors, the next question became: What benefits could a clam get from flashy lips? In a lab test, Dougherty staged a clam-versus-predator encounter. The predator, a peacock mantis shrimp with enough power in its club to break mollusk shells, approached and grappled briefly with the clam. Then the mantis shrimp backed off for intense cleaning of its mouthparts. It did not attack again, even when the clam opened up, exposing vulnerable tissue.

Some mollusks defend themselves by releasing toxic or disgusting chemicals, including acids. Dougherty has found that disco clam tissue carries an unusual abundance of sulfur. She plans to explore whether the clams release sulfuric acid.

That idea seemed plausible when Dougherty offered tidbits of clam tentacles to a mantis shrimp. The shrimp didn't eat them. Muscle from deeper in the clam's body, however, was a hit as a shrimp snack.

The predator-warning hypothesis is worth following up on, said Melissa Bowlin of the University of Michigan–Dearborn, who heard Dougherty's talk at the meeting. That's exactly what Dougherty plans to do.

But Dougherty said she isn't yet ruling out other hypotheses, such as flashing as a lure for the plankton that clams feed on. Microprey should be able to see the flashes, she hypothesizes. She has prepared mock clams, some of them flashing and some not, that she will take to disco clam country in Indonesia to see if light shows enhance the capture of food.

Another possible function of the flash, as a cue for attracting mates, seems less likely, Dougherty said. Lab tests she and Berkeley colleague Alex Niebergall ran don't support the idea that flashing attracts other clams. ■

MEETING NOTES

Highway bridge noise can disturb fish's hearing

Loud recordings of traffic rumbling over highway bridges can cause rock-concert hearing shifts in lab fish that normally live in Alabama streams. After two hours of broadcast traffic noise in the lab, small silvery fish called blacktail shiners (*Cyprinella venusta*) could no longer detect some important sounds as easily as fish not exposed to the highway din. Jenna Crovo of Auburn University in Alabama reported the findings January 5. Shiners not subjected to recordings could hear the upper peak of their species' courtship growl when tones were played at about 80 decibels. Fish subjected to traffic broadcasts didn't hear those tones until researchers played them about 10 decibels louder. Whether the threshold shift is permanent or the fish's hearing returns to normal — as often happens in human concertgoers who experience similar shifts — remains to be seen. — *Susan Milius*

Chameleon tongue power underestimated

New measurements show a chameleon tongue zapping out with the highest power output (adjusted for animal size) yet documented for a vertebrate motion. The small South African chameleon species *Bradypodion thamnobates* shoots out its tongue with up to 41,000 watts of power per kilogram of muscle involved, Christopher Anderson of Brown University reported January 6. Previous studies didn't record anything so spectacular because they focused on larger chameleons, he said. In his study of body-size relationship with tongue performance, smaller species overall trounced bigger ones in various mouth athletics. The champ for tongue power output grows only about 4 centimeters long, not counting the tail. — *Susan Milius*

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MATH & TECHNOLOGY

Computer algorithm masters poker

You've got to know when to fold 'em against this program

BY ANDREW GRANT

Even the best poker face won't work against a new superhuman cardsharp.

For the first time, a computer algorithm has solved a poker game — heads-up limit Texas Hold'em — making it unbeatable in the long run against any opponent. The work, detailed in the Jan. 9 *Science*, may help develop ways to maximize return in a business negotiation or minimize the risk of terrorist attacks — even if an adversary knows the strategy.

"It's a big step toward understanding games that are closer to real-world problems," says Murray Campbell, a computer scientist at IBM's Thomas J. Watson Research Center in Yorktown Heights, N.Y. Campbell was not involved in the study, but he helped develop Deep Blue, the computer that defeated chess champion Garry Kasparov in 1997.

The algorithm, developed by computer scientist Michael Bowling and his team at the University of Alberta in Edmonton, is the first to solve a commonly played imperfect-information game, in which participants do not have full knowledge of past events. Just as poker players must act without knowing the cards their opponent holds, researchers want algorithms that can make effective decisions based on robust but incomplete sets of data.

For decades, scientists have tried to create algorithms that win human games by blending computers' calculating prowess with the decision-making power of game theory, the branch of mathematics that computes optimum strategies in competitive encounters. In 2007, Alberta computer scientist Jonathan Schaeffer and colleagues solved the game of checkers by simulating the actions of players making the perfect move every turn (*SN: 7/21/07, p. 36*). That algorithm had a straightforward task: For each turn, it would review the positions of the pieces, evaluate options and choose the best one.

That luxury is not afforded to a computer poker player because it doesn't know what cards an adversary holds. Another wrinkle is that successful poker players are unpredictable. In checkers, the best move in a given situation is the same every time. But in poker, it's wise to bluff every now and then, perhaps increasing the bet some fraction of the time with a weak hand to throw the opponent off. "Most algorithms can't cope with that kind of uncertainty," Bowling says.

He and his colleagues at Alberta's Computer Poker Research Group chose to tackle heads-up limit Texas Hold'em because it is popular and simple. Two players each receive two cards and then can bet a fixed amount a certain number of times as five "community" cards are revealed. The game has more than 300 trillion different situations in which a player must call the bet, raise or fold.

The team developed an algorithm called Cepheus that gradually approached perfection by playing against itself. After each hand, Cepheus calculated a measure of regret, exploiting the benefit of hindsight to determine how much it had strayed from the optimal strategy. For two months, Cepheus ran on more than 4,000 computers, each playing over 6 billion hands a second; it constantly improved as it used its past regret to guide its play. After about a billion billion hands — "more hands of poker than humanity has ever played," Bowling says — the algorithm's regret came very close to zero, the measure of perfect play.

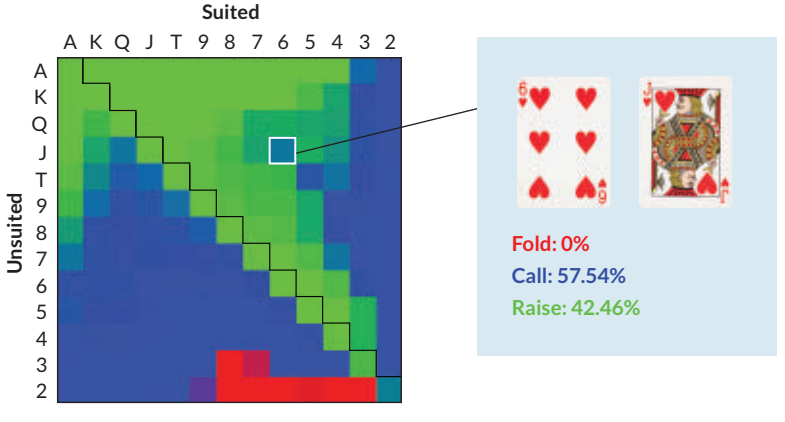
By coming up with an optimal set of probabilities for each possible scenario in a hand, the researchers ensured that Cepheus would never lose money in the long run. That would hold true even if the opponent knew the computer's strategy. Bowling says Cepheus isn't quite a perfect player, but its play is indistinguishable from ideal over the number of hands a person could play in a lifetime.

While Bowling isn't planning any computer-human poker showdowns (a computer already beat poker pros at limit Hold'em in 2008), he says the program, available online, could help amateurs learn the game. Aspiring players can square off against a perfect opponent for free rather than risk big money against seasoned but inevitably imperfect pros.

Beyond poker, Bowling says, scientists can apply this combination of artificial intelligence and game theory to major real-world problems such as nabbing terrorists at airports and catching fare evaders on transit systems. In these situations, officials need a security plan that is effective even if criminals employ a surprise attack or get hold of the plan.

Bowling's team is continuing work on three-player and no-limit Hold'em. ■

For the win The diagram summarizes Cepheus' calculations for the optimal first move for a Texas Hold'em player if his opponent, the dealer, has raised. Cells above and right of the black line are hands with two cards of the same suit; below and left, unsuited cards. Generally, the best move is to raise hands in green, call those in blue and fold those in red. But for many hands, it's best to mix things up. A player with a suited 6-Jack should call a little more than half the time and raise the rest.



M. BOWLING *ET AL*/*SCIENCE* 2015, CEPHEUS POKER PROJECT

Learn more about Cepheus' strategy at **bit.ly/poker_program**

EARTH & ENVIRONMENT

Drought linked to warming pause

Powerful Pacific winds helped reduce rain in the Southwest

BY THOMAS SUMNER

The extreme winds blamed for putting the brakes on global warming may also have contributed to the record-setting drought currently parching the southwestern United States, researchers suggested January 5.

Unusually strong winds blowing east-to-west over the tropical Pacific Ocean draw up cold water along North America's west coast, a process that scientists think is partially responsible for the recent stall in global warming. This cold water causes atmospheric changes that push rainstorms away from the region, proposes Thomas Delworth, a climate scientist at the National Oceanic and Atmospheric Administration's Geophysical Fluid Dynamics Laboratory in Princeton, N.J. The winds boosted the likelihood of a dry decade in the region to nearly 50 percent, Delworth estimates.

"If these winds persist," he said, "the drought will probably persist as well."

Since the late 1990s, the average annual global surface temperature has plateaued at about 14.5° Celsius. Because greenhouse gases continue to amass, scientists wondered where an expected one-third of a degree of total warming had gone.

In 2014, scientists pointed to abnormally strong trade winds that drag over the tropical Pacific and push surface water westward. The shifting creates a conveyor belt that pumps cold water from the depths to the surface near North America (*SN: 3/22/14, p. 12*).

This process accounts for roughly half of the missing warming, proposed Clara Deser of the National Center for Atmospheric Research in Boulder, Colo., in a separate presentation.

The cold surface water pulls heat from the atmosphere, changing atmospheric conditions worldwide, Delworth said. To uncover local effects, he and colleagues ran climate simulations with and without the potent winds.

Atmospheric changes caused by the winds create a high-pressure zone over the western United States. When water-laden clouds traveling from the west meet the high-pressure air, the clouds deflect northward, away from the drought-stricken Southwest. Delworth estimates that without the boosted trade winds, the chances of a decade with more than 15 percent less precipitation than average were about 3 percent. With the boosted trade winds, the chances of a parched decade rose to roughly 46 percent. The resulting rainfall reduction, he said, combined with record-high local temperatures caused one of the region's worst droughts on record (*SN: 1/10/15, p. 16*).

Strong Pacific winds have stalled global warming. The winds may also support the drought in the Southwest that has dried up reservoirs such as this one in Santa Clara County, Calif.

The source of the strong winds is unclear, though they seem linked to El Niño and La Niña and are expected to slacken as the planet warms (*SN: 9/6/14, p. 11*). Delworth predicts this wind weakening will reduce the region's chances of such severe droughts in the future.

The findings should help scientists recognize the warming pause's effects elsewhere around the Pacific, Deser said. ■

MEETING NOTES

Warming climate will force airplanes to shed weight

More frequent sweltering summer days will force commercial aircraft to go on a diet, new research suggests.

At some airports, effects of future climate change could as much as triple the number of days when planes face weight restrictions, Ethan Coffel of Columbia University said January 8.

Planes departing in warm, low-density air must reach higher speeds before generating enough lift to take off. If temperatures become too toasty, fully loaded planes can't get up to speed before they run out of runway.

Coffel and Radley Horton, also of Columbia, projected the number of hot days under a worst-case greenhouse gas emission scenario for airports in Denver, New York City, Phoenix and Washington, D.C. The pair predict that the number of weight-restricted days will increase by 50 to 200 percent by midcentury. In Phoenix, the number of hot days requiring a Boeing 737-800 to lose 4.5 metric tons before takeoff will go from near zero to 20 each year. For a long flight, this amounts to a roughly 27 percent reduction in passenger and cargo weight. — *Thomas Sumner*

Allergy-related Google searches parallel pollen season

Web searches about runny noses and allergy medications can help researchers track changes in pollen count.

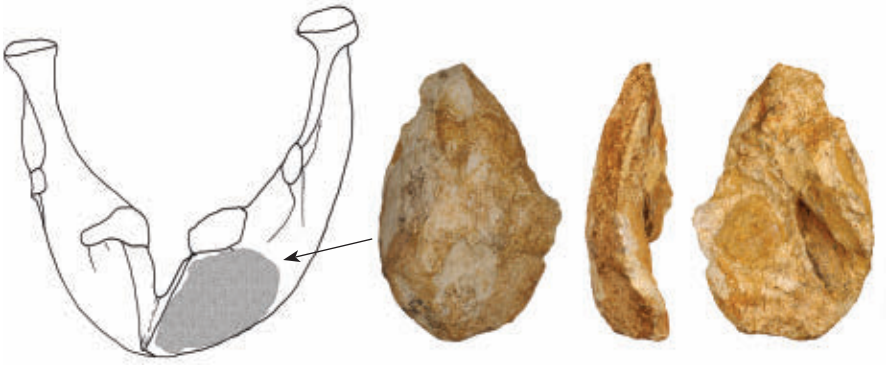
Matthew Parker of Mercer University in Macon, Ga., looked at trends in Google searches for terms such as "pollen" and "Zyrtec" from 2004 to 2011 in the Atlanta metropolitan area. Allergy-related searches peaked alongside measurements taken at two nearby pollen counting stations for ragweed, oak and pine pollen, Parker said January 7.

Web searches could help track long-term trends in pollen counts in areas without monitoring stations. The method is limited to areas with a lot of Internet users, Parker acknowledged. Tracking pollen will become increasingly important, he said, since rising temperatures and carbon dioxide levels are expected to boost pollen production. — *Thomas Sumner*

HUMANS & SOCIETY

Ancient bone hand ax found in China

Researchers say they have identified the first example of a bone, not stone, hand ax crafted by ancient humans in East Asia. Makers of the curved, pear-shaped implement probably used it to dig up edible roots around 170,000 years ago, Guangbiao Wei of China Three Gorges Museum in Chongqing and his colleagues report online January 8 in *Quaternary International*. Part of a lower jaw from a stegodon, a now-extinct, elephant-like creature, provided raw material for the tool. Excavation of a cave in South China in 2002 yielded the hand ax, along with bones of stegodons and other large animals. Until now, the artifact's age was unknown. Wei's team dated the find by measuring the decay rate of forms of uranium and thorium in the fossilized bone. Bone hand axes are rare, even outside East Asia. A handful of such tools previously unearthed in Africa, Europe and West Asia were made from limb bones, ribs and tusks of creatures such as mammoths. Stone hand axes, which preserve far better than bone artifacts, date to 800,000 years ago in South China (*SN: 3/4/00, p. 148*). — *Bruce Bower*



This 24-centimeter-long hand ax, shown from three angles, is the earliest known bone hand ax from East Asia. Ancient humans used part of a stegodon jaw to make the 170,000-year-old tool.

GENES & CELLS

Cold noses coddle colds

Chilly winter weather alone does not cause colds, but cold weather may numb the body's ability to fight off cold viruses. Rhinovirus, also known as the common cold virus, grows better in the nasal passages than in the lungs, but the reason hasn't been clear. Now, Ellen Foxman of Yale University and colleagues find that the virus-fighting signals given off by infected host cells don't raise as much of an alarm at 33° Celsius, the temperature in the nose, as they do at the core body temperature of 37° C. Using a rhinovirus adapted to grow in mouse cells, the team discovered that infected cells in mouse airways produce less interferon — an antiviral defense molecule — when grown at nose temperature than they do when grown at the lungs' core body temperature. A molecule called the RIG-I-like receptor, which helps activate the body's defense system, also doesn't work as well at cooler temperatures, the team reports online January 5 in the *Proceedings of the National Academy of Sciences*. Inhaling cold air may repress the ability of cells lining the nasal passages to fight off cold viruses. — *Tina Hesman Saey*

BODY & BRAIN

Asthma may add to sleep apnea risk

People with asthma are more likely than nonasthmatics to develop obstructive sleep apnea, a long-term study finds. The report, in the Jan. 13 *JAMA*, solidifies a link between the two breathing disorders, though it is unclear whether asthma might cause sleep apnea. Mihaela Teodorescu of the University of Wisconsin–Madison and colleagues analyzed data from participants in the Wisconsin Sleep Cohort Study, which tracks sleep disorders in adults who undergo a lab-supervised sleepover session every four years. The team looked at 81 volunteers with preexisting asthma and 466 nonasthmatics who had been in the study for at least four years. The researchers accounted for differences between the groups in sex, age, nasal congestion, smoking status, alcohol consumption and body mass index. The risk of developing obstructive sleep apnea during the first four-year period was 39 percent greater in the asthma group, and the risk of developing apnea plus daytime sleepiness was 2.7 times as high. When researchers analyzed data from 468 people who had been in the study for more than eight years, 49 percent of those who had preexisting asthma developed obstructive sleep apnea compared with 28 percent of the others. Using regular lab tests to study sleep apnea eliminated some of the vagaries of self-reported sleep problems, Teodorescu says of her research. — *Nathan Seppa*

EARTH & ENVIRONMENT

More toxic chemicals found in water left over from oil and gas production

Whether trickling from cracked shale deep underground or gushing through an old-school well, wastewater from oil and gas production may carry two potentially dangerous components besides those previously known. Harmful levels of ammonium and iodide have been found in wastewater from conventional oil and gas production and from the more controversial practice of hydraulic fracturing, or fracking. The chemicals, pulled up from the Earth, arrive at the surface at concentrations high enough to harm aquatic life and form cancer-causing compounds when mixed with the chlorine in tap water, researchers report online January 14 in *Environmental Science & Technology*. A team led by Avner Vengosh of Duke University tested water from conventional wells, fracking sites, oil and gas wastewater treatment facilities and a wastewater spill site. Samples came from Pennsylvania, West Virginia, New York and Arkansas, and many had high levels of ammonium and iodide. Even treated wastewater had levels of ammonium up to 50 times higher than the maximum levels found to be safe by the U.S. Environmental Protection Agency. — *Beth Mole*

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High Fliers

Scientists are turning to the animal kingdom to inspire the next wave of small drones.

NICOLLE RAGER FULLER

Avian acrobats teach drones some masterful maneuvers

By Nsikan Akpan

Ty Hedrick stands on a riverbank watching an aerial clash between two foes.

An intruder has ventured into restricted airspace and must flee as quickly as it came. The wind shifts as the pursuer dips when the invader dips, curls when it curls. They match each other step for step, or more accurately, wingbeat for wingbeat.

The battle pits two cliff swallows (*Petrochelidon pyrrhonota*) against each other, midnight blue on their backs and pumpkin orange on their throats.

For Hedrick, a biologist at University of North Carolina at Chapel Hill, swallows are the top guns of the animal kingdom. As the birds careen overhead, Hedrick captures their deft maneuvers, snapping 100 images per second with three high-speed cameras. He and his team trace the positions of cliff swallows as they battle for territory. Through research like this, the scientists have learned that the birds perform extreme high-speed turns that would incapacitate the best human fighter pilots. The researchers published their latest findings on the birds' moves last August in the *Journal of Experimental Biology*.

Hedrick has become a swallow voyeur as part of a nationwide coalition of engineers building a futuristic fleet of aerial drones. The drones will range from hummingbird-sized to those as broad as some eagles. Each is inspired by flying animals, both in body architecture and brain wiring.

"We're not trying to replicate nature, but harness basic principles," says aerospace engineer Kristi Morgansen of the

University of Washington in Seattle, who leads one of two animal-inspired projects funded by the U.S. Office of Naval Research. Both teams are tackling things that existing drones can't do, such as think for themselves or pull tight maneuvers in crowded places.

Morgansen's team, dubbed AIRFOILS (for Animal-Inspired Robust Flight with Outer and Inner Loop Strategies), is constructing autonomous drones that "feel" their environment. The other bioinspired team is run by Russ Tedrake, director of the Center for Robotics at MIT's Computer Science and Artificial Intelligence Lab. Its name is even more of a mouthful: Provably Stable Vision-Based Control of High-Speed Flight through Forests and Urban Environments. That project's goal is to build drones that can speed through a forest or a city while dancing through trees or between buildings. The two projects split $15 million in funding.

"We hope these programs will create a new generation of relatively lightweight, cheap systems that can fly through very complex environments," says Marc Steinberg of the Office of Naval Research.

If all goes well, the new and improved unmanned aerial vehicles, or UAVs, will sport flexible wings, like birds' or bats', that bend when they brush against an object like a tree branch. To help maneuver in turbulent weather, their wings will sense the wind as it rushes by. Since the project began in 2010, the teams have moved closer to these goals, crafting drones that drop onto perches and instinctively avoid objects in their way.

The researchers envision drones that will fight forest fires, spot poachers on the savanna and catch environmental polluters. Some drones carrying packages will zip through offices, dodging people and each other, all self-directed. The Federal Aviation Administration predicts that 30,000 drones of all sizes will fill domestic skies by 2030.

But they'll need to know how to behave. To craft the next armada of microdrones, scientists are glancing skyward to see what can be learned from nature's high fliers.

Tracking a flying ninja

Until Hedrick's study, detailed investigations into avian aerodynamics and biomechanics were confined to wind tunnels, which are basically hamster wheels for birds.

"In the past, you could record from muscles while they were contracting and obtain measurements of a bird's physical limits," says biologist Andrew Biewener of Harvard University. "But you couldn't track flight performance over a broad range of behaviors or in a large-scale natural environment."

Such was the situation when Hedrick joined Biewener's lab as a graduate student in 1999. But Hedrick and Biewener soon added new toys to the classic wind tunnel experiment: high-speed video cameras. By positioning five cameras around a wind tunnel, the two could monitor a bird's shoulder joint as it rotated during each flap, producing lift. They could track every feather as it bent.

Before this innovation, flapping and maneuvering were just too fast to track accurately. Multiple shooting angles brought more freedom. The researchers built an L-shaped tunnel to watch cockatiels, their favorite bird at the time, turn a corner.

Hedrick brought some unique skills to the table after working two years in e-commerce in San Francisco. When he returned to research (he had earned a bachelor's degree in biology at Brown University in Providence, R.I.), he built software that could take a video recording and mine every facet of a wing's motion. Each video frame contained thousands of visual points — pixels — on every feather. With multiple cameras, a single run might collect millions of data points that trace the contours of a moving wing.

Hedrick, Biewener and colleagues created computer programs to extract treasure from this data dump. They used the software to gauge how much power a turtledove wingbeat produces and how cockatiels contort their wings and accelerate. Results of the studies appeared in 2003 in *Nature* and 2004 in the *Journal of Experimental Biology*.

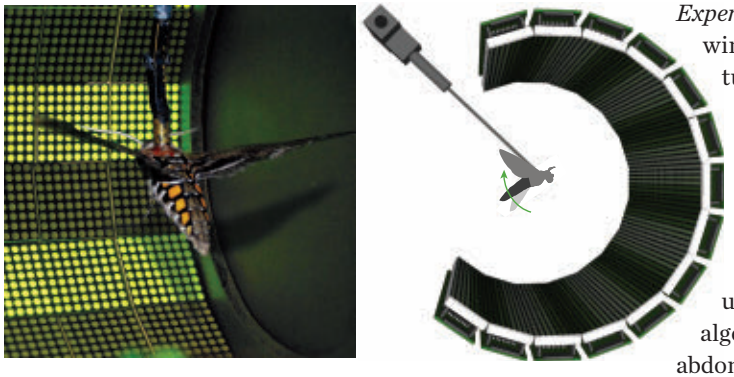
"Today, we're at the beginning of a whole new understanding of how animals fly, and Ty has absolutely been a pioneer," says comparative physiologist Douglas Altshuler, who uses Hedrick's open-source algorithms to study hummingbird flight at Vancouver's University of British Columbia.

In 2012, Hedrick and colleagues at Boston University adapted this technology to move their studies of avian biomechanics outside. Swallows make for great outdoor subjects because of their endurance and acrobatics. The birds cruise out in the open and fly practically nonstop for 13 hours a day. "It's just insane," says Bret Tobalske, director of the University of Montana Flight Laboratory in Missoula. He works with Hedrick on a separate project involving barn swallows (*Hirundo rustica*) in Oregon.

Swallows are aerial ninjas — both in the way they chase food and compete for territory. They have evolved deft maneuvers to catch elusive prey, such as dragonflies, grasshoppers,

MIT's model drones: Some detect oncoming obstacles using motion trackers, then "knife" sideways to avoid them (top); the Phoenix ornithopter (lower left) flaps like a bird carrying 400 grams of onboard computer plus sensors; some drones (lower right) can dodge objects such as goalposts.

CLOCKWISE FROM TOP: ANDREW J. BARRY/MIT; A.J. BARRY/MIT; JASON DORFMAN/MIT



Twerk it Researchers use a curved panel of LED lights (right) and high-speed cameras to examine hawk moth hovering. The insect bends its thorax-abdomen joint to turn toward the light. This little twerk stabilizes its flight, allowing the moth to turn while hovering.

moths and flies. Barn swallows, for instance, hunt by zipping back and forth across a field. The birds "hug the deck," flying just above the ground, as insects coast overhead. When a swallow sees a juicy bug, it swings up and snaps its beak around its meal. Then like a pendulum carnival ride, the bird swoops back down, heading in the opposite direction. The whole flight takes a few seconds.

When cliff swallows compete for territory, their sprints and turns can be surprisingly mild, given what the birds are capable of, Hedrick observed in the 2014 *Journal of Experimental Biology* paper. The birds flew at an average of 25.2 kilometers per hour, even though their maximum sprint can reach more than double that: 56.2 km/h. Cliff swallows can also execute extreme turns, with one outlier maxing out at 7.8 g-force. That's more force than any roller coaster; the Tower of Terror in Johannesburg, South Africa, considered the most forceful, maxes out at 6.3 g's.

Hedrick thinks the breakneck speeds and banks cause extra fatigue for muscle and bones. After the freakish 7.8-g maneuver, the birds' speed dropped immediately from 52.6 to 16.2 km/h.

The study revealed that flapping gives birds the flexibility to make hard turns while flying swiftly or slowly. Now the AIRFOILS team is deconstructing and rebuilding the minutia of the swallows' flight for drone maneuvering.

Staying airborne

By investigating the common features of different species — bats, swallows, hawk moths and bees — the AIRFOILS team hopes to isolate the keys for agile flight. For instance, Carolina hawk moths (*Manduca sexta*) are nimble fliers similar to hummingbirds in wingspan and zippy style. Hawk moths dart around, then suddenly pause to hover. They levitate so steadily that they can recover within three wingbeats after being hit with a clay cannonball, Hedrick's team reported at the 2011 Society for Integrative and Comparative Biology conference. The insects manage this without the muscles and bone structure that their avian counterparts use to maneuver. But how?

Hedrick and Daniel reported in 2006 in the *Journal of Experimental Biology* that hawk moths sweep and bend their wings in as many as 20 different orientations to dampen turbulence while hovering. Plus, they take advantage of a surprising move. The researchers like to call it twerking.

Morgansen and another AIRFOILS member, University of Washington biologist Tom Daniel, saw this special dance when they put hawk moths into a semicircle arena covered with LED panels. In the same way they would react to a flame, the moths turned toward the lit-up LED lights. By using high-speed video and Hedrick's algorithms, the team learned that hawk moths wiggle their abdomens to quickly pivot up or down, as reported in the *Journal of Experimental Biology* in 2013.

By attaching abdomen-like appendages to a helicopter-style drone with four propellers, known as a quadrotor UAV, Morgansen and Daniel tried this piloting concept. The artificial abdomen would pivot as the drone pitched up and down. The appendage stabilized the drone's flight, which they reported in 2012 at the 15th International Conference on Climbing and Walking Robots and the Support Technologies for Mobile Machines.

Future autonomous drones will also need to learn how to feel the air. A strong wind will hardly throw a bird or an insect off course, because it can feel the squall and adjust its wings. Can drones do the same?

"Most people believe every feather is used as an aerodynamic sensor," says MIT's Tedrake. When the wind pushes against these sensors, they send nerve signals to the brain and trigger reflexive movements. Each gust is like a finger prick that causes birds to instinctively contort their wing shape, which is known as actuation, to relieve the strain.

Hawk moths use wing sensors to assist in flight control too, Daniel's team reported last July in the *Journal of Experimental Biology*. Hawk moths use their wing sensors much like flies use halteres, special organs behind the wing that serve as a biological gyroscope, sensing the insect's body rotation during flight.

By scanning the animals' motions, Morgansen says, researchers are learning where to place artificial sensors on drones.

Dodge and weave

If the future involves drones crowding the sky, the machines will need sharp visual systems to work along with their wind sensors. Akin to Luke Skywalker's speeder bike instinctively dodging trees on the forest moon of Endor, these drones must sense objects as they approach and dance around them.

Tedrake's team is on it, having designed a visual system that can recognize oncoming impediments and turn the drone.

One example from Tedrake's lab, called push broom stereo, behaves like working memory in birds and humans. As reported last July at arXiv.org, the computer program uses two small cameras on a drone to scan the space about five meters in front of the drone. When an obstacle appears, push broom temporarily remembers the object's position so the drone can evade

JONATHAN P. DYHR *ET AL/JOURNAL OF EXPERIMENTAL BIOLOGY* 2013

Learning from the best

Researchers are studying the behaviors of the best fliers in the sky to teach small, unpiloted drones a thing or two.

Swallows
Wing rotation and positioning enable breathtakingly sharp turns; energy-saving tactics aid long flights.

Bats
Bats swarm out of caves in well-orchestrated, group behavior and skillfully avoid colliding with each other.

Honeybees
Widening one wing's angle and narrowing the other's, honeybees quickly recover when hit with a gust of wind.

Hawk moths
Flexible wing movements and bendable body parts enable controlled hovering and zipping.

it. Initial flights were manually piloted, but the authors say they are confident that the system could autonomously avoid the obstacles, as well. Once past, its memory banks forget the obstacle. This amnesia means that engineers can use smaller computers for piloting, which translates into smaller drones.

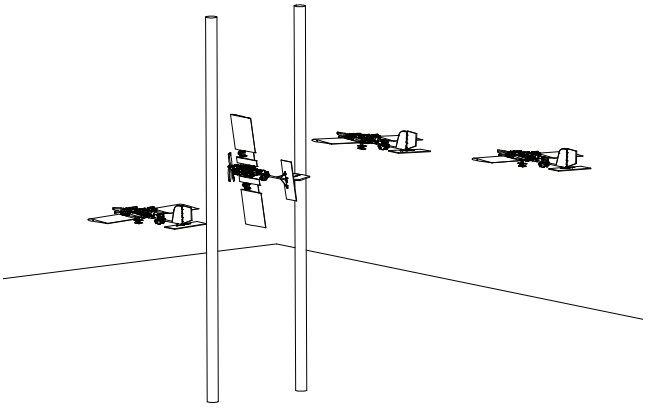
A push broom drone can fly at 32 km/h, snapping images at 120 frames per second to take in its surroundings. It is the fastest vision system on a small UAV, according to Tedrake's group.

Future drones must also be flexible enough, physically and cognitively, to react. Last year at the IEEE International Conference on Robotics and Automation, Tedrake's lab presented another artificial pilot that lets a drone twist like a bird, quickly turning sideways and zooming between two narrow posts, before swinging back into a horizontal position.

His team has also figured out how to instruct a small glider to hit the brakes and land on a perch. This maneuver — known as a stall — typically causes a fixed-wing aircraft to crash.

"Most of our best control systems on fighter jets, they don't let you stall your wings. But birds do it routinely," Tedrake says. "Do the jets need more dexterous wings or more flexible brains? Our early results suggest the latter."

In the June *Bioinspiration & Biomimetics*, Tedrake and colleagues reported a computer algorithm that can read airflow over the glider's wings and autonomously control its tail, piloting the craft onto a perch. In the future, the researchers plan to program this maneuver into a drone's onboard computer so it can perch on power lines and recharge.



Cutting through This schematic shows a 71-centimeter wingspan drone from MIT's Russ Tedrake that swings — or rolls — its frame to cut between obstacles spaced 70 cm apart.

Future aerial traffic jams might also be avoided by taking a lesson from how flying animals behave in swarms.

For instance, cliff swallows host annual roosting flights, swarming over fields. "Several hundred birds will engage in massive synchronized flights, where the whole group flies as one," says behavioral ecologist Charles Brown of the University of Tulsa, Okla. He has monitored more than 229,000 cliff swallows in western Nebraska over the last three decades.

"It'd be cool if instead of pairs, one of Hedrick's future studies tracked 300 birds," Brown says.

That prospect might soon be within reach. Computer scientists Diane Theriault and Mikhail Breslav, doctoral students at Boston University, have partnered with Hedrick to expand the scope of multicamera videos to examine swarms of flying animals, such as bats and swallows. Theriault has constructed algorithms to track dozens of individual free-tailed bats as they emerge at dusk from caves in Texas. And Breslav is adding infrared technology to monitor those nighttime flights.

Hedrick's lab has recently used these tracking algorithms to create a three-dimensional simulation of a flock of chimney swifts (*Chaetura pelagica*). During their autumn migration, swifts form a large tornado-shaped flock of over 2,000 birds just before they dive into a chimney to roost overnight. "That landing guidance behavior is similar to how you might collect a flock of small drones after they were deployed," he says.

"A lot of the cool stuff will use these mathematical approaches to figure out how animals control their movements," Morgansen says. "We don't have all the answers yet, but I'm sure that they'll be good." ■

Explore more

- Kristi Morgansen. "Autonomous fish robots and bio-inspired engineering." TEDxRanier. bit.ly/SN_fishbots

Nsikan Akpan is a science writer based in Washington, D.C.

CLOCKWISE FROM TOP LEFT: PAUL HURTADO/FLICKR (CC BY-SA 2.0); RON GROVES/EOL.ORG; DAVID CAPPAERT/MICHIGAN STATE UNIVERSITY/BUGWOOD.ORG; KILEY RIFFELL/FLICKR (CC BY 2.0); A.J. BARRY *ET AL*/*ICRA* 2014

To learn about swallow tracking and see drones in action, visit **bit.ly/SN_highfliers**

Big Data, Big Challenges

As researchers begin analyzing massive datasets, opportunities for chaos and errors multiply

By Tina Hesman Saey

In my quest to explore the unknown frontier inside my own body, I stumbled upon one of the most intractable problems facing science.

The issue, irreplicable results, is a dark cloud looming over the life and social sciences. My encounter began when I sent identical stool samples to two microbiome sequencing services (*SN Online: 6/17/14*). The microbiome is the community of microbes that live in and on the human body, and studies had suggested that it shapes health and even behavior. My goal was to find out what bacteria inhabit my intestines, the most microbe-packed part of the body.

I thought the process would be straightforward: the two services, American Gut and μBiome, would examine the DNA from the microbes in my gut and tell me what was in there. But when the results came back I was no wiser than before — just confused. The profiles presented by the services showed wildly different results. For example, they reported almost completely opposite readings on the proportions of Firmicutes and Bacteroidetes, two of the major phyla of bacteria found in the human gut. This was frustrating because the mix of these two may determine whether someone is obese or not and affect other aspects of health. I thought that, at a minimum, I would learn how many of these major players inhabited my gut (*SN: 1/11/14, p. 28*).

Although the bacteria, viruses and fungi that microbiome scientists study are microscopic, the amount of information needed to catalog the microorganisms and figure out their effect on the body is massive. For one sample like mine, there may be hundreds of different types of bacteria, and thousands of bits of DNA to sequence and analyze. To tell me how my personal mix stacks up, the researchers compared my sample with thousands of other people's. But to discover the impact of different microbes on health, scientists might analyze hundreds or thousands of samples, each containing its own ecosystem of myriad microbes. If two labs couldn't get my sample right, what does that say for the vast studies cataloging the bacteria involved in human health and disease?

> Microbiome researchers aren't the only ones having a tough time replicating results.

When I tweeted and blogged about the anomalous findings, people who study the microbiome confessed that they were not surprised my results differed so starkly. They had encountered this problem before, and now they were preparing to tackle it. I was invited to watch.

Microbiome researchers aren't the only ones having a tough time replicating results. Retractions and corrections in the scientific literature are on the rise. Scientists are hotly debating both the sources of and solutions to the problem that is rocking science (*SN: 1/24/15, p. 20*).

It is hard enough to duplicate findings from studies with a handful of mice or people. But extend the work to include thousands or millions of data points collected from huge numbers of research subjects — the kind of work done in the expanding field of genomics, for example — and the room for error grows by leaps and bounds.

Microbiome research is just one of many flavors of the "big data" projects that have become ubiquitous in the life sciences. For genome-wide association studies, researchers track hundreds of

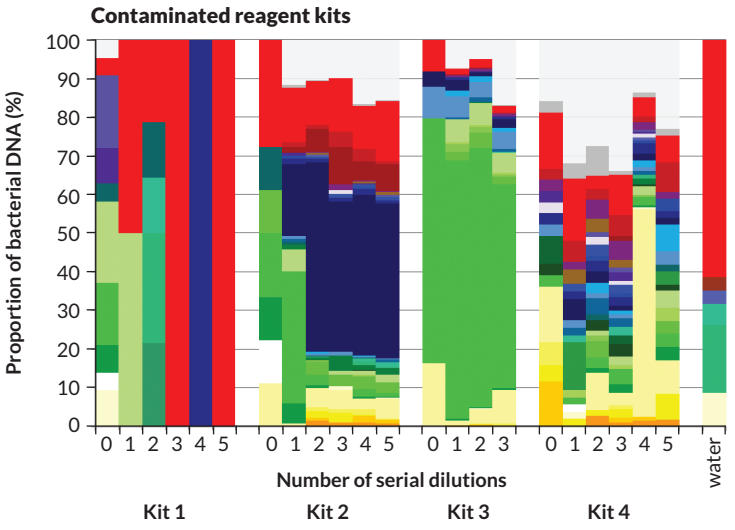
Replication anxieties

THIS ISSUE

This feature is the second installment of a two-part series examining problems plaguing efforts to replicate scientific studies.

To read Part 1, "Repeat Performance," see *SN: 1/24/15, p. 20* or visit sciencenews.org/replicability

OPPOSITE: JAMES PROVOST



Dirty work Researchers found contamination in four reagent kits as well as a sample of "ultrapure" water. Colors indicate different types of bacteria. If the kits were clean, the columns would be blank. Contamination may make comparing results between labs difficult. SOURCE: S. SALTER *ET AL/BMC BIOLOGY* 2014

thousands of DNA variants in tens of thousands of people to find genetic contributions to common diseases. In sequencing studies, geneticists are collecting billions of bits of DNA data on hundreds to thousands of research subjects from lab animals to humans. Brain scientists are attempting to map all of the 86 billion neurons in the human brain and catalog the trillions of connections they make with other neurons. The list goes on.

Big data projects are officially defined as those that generate so many pieces of information that computers are needed to sort through it all. But that doesn't begin to capture the scope of these efforts.

Daniel MacArthur, a geneticist at the Broad Institute of MIT and Harvard, formed a coalition called the Exome Aggregation Consortium with 23 other scientists and their research associates. The group has pooled genetic data from the exomes, or protein-coding parts, of more than 90,000 people's genomes. The database holds about 925 terabytes of raw data — more than nine times the size of the print collection of the Library of Congress. And more genomes are being added all the time. Plenty of other researchers are generating their own enormous masses of data.

Buried in that data are potential gold mines. A recent study of 2,430 bacterial genomes, for example, showed that friendly microbes can make 44,000 small molecules, including some that could be useful antibiotics (*SN: 10/18/14, p. 8*). Researchers are sifting through mounds of data to find and scrutinize similar nuggets to develop better drugs or make connections between genetic variants and diseases. Yet, as science moves toward big data endeavors, so grows the concern that much of what is discovered is fool's gold.

Just keeping track of big data is a monumental undertaking. Sharing the data with other researchers, a critical piece of transparency and efficiency in science, has its own set of problems. And the tools used to analyze complex datasets are just as important as the data themselves. Each time a scientist chooses one computer program over another or decides to investigate one variable rather than a different one, the decision can lead to very different conclusions.

For instance, two groups of researchers applied different analyses to one dataset containing gene activity measurements from mice and humans injured by trauma, such as burns or blood infections. One group concluded that mice are terrible stand-ins for people with inflammation caused by trauma (*SN: 3/23/13, p. 10*). The other group decided that the rodents are excellent human analogs (*SN: 9/20/14, p. 14*). Same data, opposite results.

Optimists within the scientific community hope to avoid at least some pitfalls by learning from others who have conquered similar challenges before. For example, researchers who study gene activity with devices known as microarrays, available since the mid-1990s, were among the first biologists to encounter the big data dilemmas. They have stepped through technical problems and are perfecting ways to allow disparate research groups to directly compare their data.

Sorting out the weaknesses

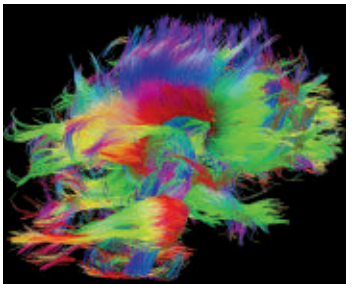
Studies of the microbiome produce some of the hottest papers in biology today. But, as I discovered, results in one lab don't always match up with those from another. For Rashmi Sinha, an epidemiologist at the National Cancer Institute, and others, the disagreement between labs means that conclusions about how microbes affect health can't be fully trusted. With nearly every aspect of human biology dependent on microbial actions, microbiome researchers need to be able to count on their data.

The first step in slaying any dragon is learning its weaknesses. Sinha masterminded a plan to probe for soft spots in the way scientists collect, process and analyze microbiome data. The project is known as the MBQC, for microbiome quality control. Many of the top labs in

the field eagerly signed up.

Last autumn, about 60 microbiome researchers and observers met in Rockville, Md., to talk about testing for vulnerabilities in microbiome studies.

Sinha and microbiologist Emma Allen-Vercoe of the University of Guelph in Canada had prepared 96 standardized samples of bacteria or DNA for the researchers to examine. In the project's pilot phase, 15 laboratories handled and sequenced the microbiomes, then handed their data to nine labs for computer analysis.



The big data Human Connectome Project is mapping the circuitry of a vast number of neurons in human brains. Colors here indicate direction of water flow, an indirect measure for locating nerve fiber connections.

Each lab was encouraged to follow its normal procedures and closely document each step. "It's surprising how many little things each lab chose to do differently," says Curtis Huttenhower, a computational biologist at the Harvard School of Public Health. For instance, researchers used diverse methods to crack open the bacteria and pull out the DNA. Analysis methods varied widely as well.

The idea wasn't to judge whose choices were better. Instead, the researchers wanted to know which steps injected chaos into the system.

A few procedural decisions affected the final results. One lab that studies the vaginal microbiome used a unique set of tools, called PCR primers, to make copies of the DNA. That lab counted a different amount of diversity of microbes than the rest of the labs. The DNA extraction methods mattered, too, as did the analytical techniques.

That's the boring news, Huttenhower says. True, such variables are a source of error that could lead researchers to detect patterns that aren't due to the underlying biology. But the exciting result, he says, was that even with the technical differences, researchers were still able to reliably differentiate samples from sick people from those of well people. The result gives him hope that veins of biologically meaningful information run through the mountains of data.

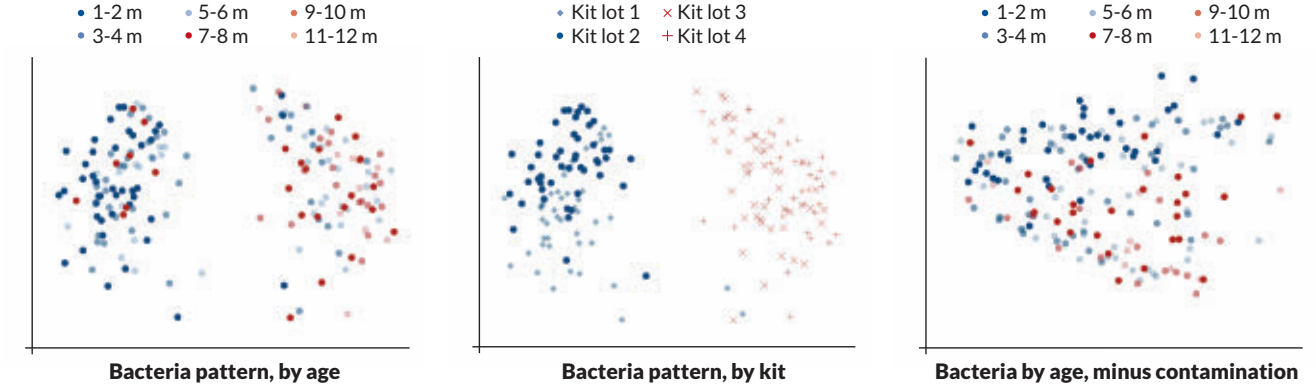
Sometimes, however, hidden menaces are so noisy that they drown out the real biological message. Contamination is one such menace, Susannah Salter of the Wellcome Trust Sanger Institute in Hinxton, England, and colleagues discovered. Sterile water and reagent kits that scientists use to pull DNA from microbial samples may already contain significant amounts of bacterial DNA, the researchers reported last November in *BMC Biology*. Contaminating DNA may dominate samples, throwing off results.

Salter and her colleagues described one such instance: A study of how children's microbiomes develop that took place in a refugee camp on the border between Thailand and Myanmar. A group of infants born in 2007 and 2008 had their noses and throats swabbed every month until they were 2 years old.

At first it looked as if soil bacteria such as *Achromobacter* and *Herbaspirillum* are the first to grow in infants' noses and mouths. But the finding made Salter suspicious. "The things we were seeing were not normal human bugs," she says.

Because her Thai colleagues kept meticulous

Confounding contamination Tracking microbe changes in babies, researchers thought they had found a pattern related to age in months (left). But the pattern that characterized the bacteria (middle) was caused by contamination in two of the kits used to extract the DNA (kits 1 and 2). Without contamination the pattern disappeared (right).



FROM TOP: COURTESY OF THE LABORATORY OF NEURO IMAGING AND MARTINOS CENTER FOR BIOMEDICAL IMAGING, CONSORTIUM OF THE HUMAN CONNECTOME PROJECT; S. SALTER *ET AL*/*BMC BIOLOGY* 2014, ADAPTED BY J. HIRSHFELD

records, Salter was able to determine that the soil bacteria were not growing in babies' noses. Instead, DNA from soil bacteria had somehow contaminated two of the kits used to process the samples, completely obscuring the organisms that were really present.

Contamination doesn't end with lab reagents. It can be enshrined in digital format in large databases, Steven Salzberg of Johns Hopkins University and colleagues reported in November in *PeerJ*. The researchers found that the genome of *Neisseria gonorrhoeae*, the organism that causes gonorrhea in people, was contaminated with stretches of DNA that actually came from cows and sheep. Four other genomes the researchers randomly selected from the public database GenBank also contained sequences from other species, indicating that many more genome records may also be tainted.

These types of challenges are to be expected when working with big data, researchers say.

"Anything that provides a lot of very sensitive data provides a lot of truth and a lot of noise," Huttenhower says. Scientists need to know about and account for the noisemakers in their studies. Huttenhower prefers telling people what to look out for rather than being prescriptive. Forcing scientists to conform to a single protocol would be a mistake, he says.

Go big or go home

While it is easy to get lost in big data and see patterns where none exist, sometimes the problem with big data is that it's not big enough.

MacArthur and other scientists in the Exome Aggregation Consortium are trying to track down very rare mutations that cause diseases. MacArthur focuses on muscle diseases, such as muscular dystrophy and congenital myopathy.

He and colleagues must comb through about 30 million DNA bases that make up one person's exome to find the one or two mutations that cause the disease. That task would be hard enough, but it is further complicated because even a healthy person's genome carries about 20,000 to 30,000 genetic variants. How can scientists tell whether what they've found is really a disease-causing mutation and not a benign rare variation? Often they can't.

A study published in *Science Translational Medicine* in 2011 found that 27 percent of variants identified as the causes of inherited rare diseases either turned out to be fairly common or were mislabeled. To MacArthur, the implications are clear: "All of us who have done rare disease discovery in the last decade have almost certainly misdiagnosed patients."

The solution to the problem? Go bigger. MacArthur and colleagues realized that pooling data from huge numbers of people in the Exome Aggregation Consortium would give them a better picture of just how common variants are in the population. Armed with that knowledge, researchers can be more confident that the mutations they discover really are rare and the likely cause of a disease.

"The impact of big data on science is unquestionably a force for good," says MacArthur. "It sweeps away false positives."

But creating the database was no easy task. Each project that contributed data generated it differently, MacArthur says. He and others spent nearly two years developing software to harmonize the data from disparate sources.

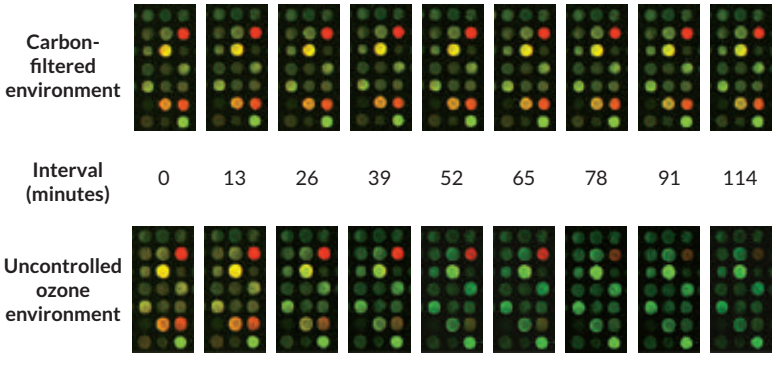
Messy data

Big data sharing is an ordeal that is all too familiar to Santiago Pujol, a civil engineer at Purdue University in West Lafayette, Ind. Pujol and colleagues are creating a virtual platform to allow 15 labs involved in an earthquake engineering project sponsored by the National Science Foundation to store and share their data.

"What we got was quite challenging," Pujol says. Sometimes data files would arrive with no explanation of the type of information contained within, or measurements would be labeled but didn't include units. "You didn't know if they were measuring in millimeters or inches," Pujol says. In short, it was a mess.

Pujol's experience is not unusual. For the MBQC, Huttenhower thought he had given the

Ozone disarray Microarrays measure gene activity, with each spot representing a different gene. Ozone degrades a red dye used in the devices, erasing indications of real differences in gene activity (bottom). Filters that scrub ozone out of the air enable much more reproducible results (top).



W. BRANHAM *ET AL*/*BMC BIOTECHNOLOGY* 2007

microbiome researchers precise instructions for how to present sequence data to the analytical labs, but he says he still got a variety of file types and data formats that had to be reconciled before the computer programs could analyze them.

Pujol and others say that standards for presenting and storing data could go a long way toward making research of all types more reliable.

Safer ground

Big data researchers are hoping to learn from the microarray pioneers who have already tackled some of these replicability challenges. Researchers who use these devices to measure gene activity were some of the first prospectors in life science's big data rush.

Microarrays use a red and a green dye to measure gene activity and are widely used in studies comparing how disease or environmental conditions, such as exposure to chemicals, affect cells.

> "You spend all your time doing these experiments, so you want to know you're getting it right."
>
> SARAH MUNRO

Kristopher Kilian, a chemist at the University of Illinois Urbana-Champaign, worked at microarray-maker Rosetta Inpharmatics in the early 2000s when the technology was catching fire. The company was fielding complaints from users that results of experiments changed with the seasons. Then some of the microarrays caught "measles," the company nickname for a strange pattern in which red dots ringed in green appeared on the microarrays.

The measles struck when the company built its new microarray processing facility next to a freeway, and they peaked with rush hour traffic. Finally, Kilian's group determined that ozone produced by cars was degrading the red dye, and suggested in *Analytical Chemistry* in 2003 that researchers keep levels of the gas low. Ozone also varies by season, with higher levels floating around in the summer, and could explain why researchers were getting different results at different times of year.

Carbon filters that scrub ozone out of the air dramatically improve the reliability of microarray experiments, another group of researchers reported in 2007 in *BMC Biotechnology*.

Working out technical problems was just the first step. It took several years of software development to make experiments done in various labs using the same type of microarray comparable with each other. And researchers still have trouble reconciling experiments that rely on microarrays produced by different companies, and yet more difficulty comparing the results with new technologies such as RNA sequencing, a more sensitive way to measure gene activity. Researchers adopting the new technology would like to reconcile their fresh-off-the-sequencer results with older microarray findings, but currently they can't.

Even that hurdle may be surmountable. Biomedical engineer Sarah Munro of the National Institute of Standards and Technology in Stanford, Calif., and colleagues have developed a set of 96 standardized RNAs for use as internal quality controls to tell how well researchers are performing each step of their experiment. The standards should allow researchers to calibrate their results to those from other labs and possibly match up microarray data with RNA sequencing results. Computer software that the researchers call a dashboard allows scientists to try out several types of analysis on their data to see how the final outcome might change.

Eleven of 12 labs that tried the standards showed consistent performance, Munro and colleagues reported last September in *Nature Communications*.

"You spend all your time doing these experiments, so you want to know you're getting it right," says Munro. She hopes the standards will help other researchers better evaluate and replicate results. "It's about people being able to communicate their measurements and have confidence in them," she says.

It has taken more than 15 years for microarray technology to develop enough so that scientists can easily compare their data. Researchers conducting other types of big data studies hope that the lessons learned from more mature fields will help catapult them past pitfalls to safer ground where data can be trusted. With data shooting from sequencing machines and other high-throughput laboratory equipment like water from a fire hose, it has never been more important that researchers learn what it takes to make their results as reliable as possible. ■

Explore more

- Oregon State University. "Unsolved mysteries of human health: Microarray — how does it work?" bit.ly/SN_OSUmicroarray
- Human Connectome Project: www.humanconnectomeproject.org
- Human Microbiome Project: commonfund.nih.gov/hmp/index

The Maasai people in Kenya have herded cattle sustainably for generations.

TELEVISION

‘Earth: A New Wild’ puts people in the picture

Nature documentaries tend to give glimpses of pristine landscapes, breaching whales and fantastic bird mating displays. But the vistas often ignore something very important: the people just out of the camera’s view.

In the five-episode documentary *Earth: A New Wild*, which airs beginning February 4 on PBS, the focus is not just on the animals. M. Sanjayan, a conservation scientist, takes viewers around the world to see animals and the human-influenced ecosystems they inhabit. The program demonstrates how animals successfully coexist — or don’t — alongside our growing human population.

Earth: A New Wild
PREMIERES FEBRUARY 4
PBS | *Produced by National Geographic Television with Passion Planet*

It might be hard to envision connections between logging and herring spawn, vultures and Hinduism or oysters and New York City. But in each episode, Sanjayan shows that ecosystem connections run deep.

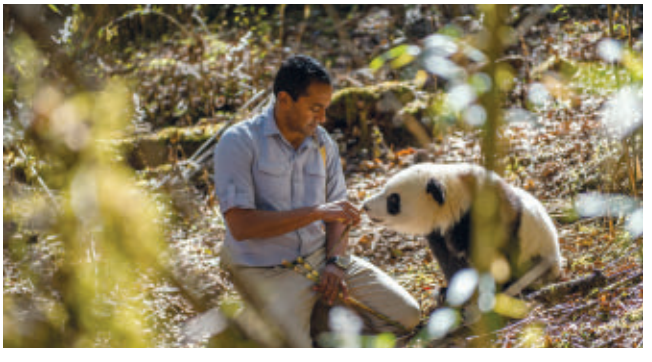
In one episode, huge clouds of spawning herring in the bays of British Columbia provide food for salmon. Salmon swim upstream to breed. On the way, some are caught by bears, which range deep into the forest. The fish bones and heads the bears leave behind form an important source of fertilizer for trees several miles from shore. The trees themselves prevent erosion, keeping the bays in pristine condition for spawning herring. Sanjayan describes how breaking just one of these delicate strands — by logging or overfishing, for example — sets off reverberations all over the ecosystem. Simple measures, such as restricting logging of trees in the area, can make an important difference.

Each episode focuses on a particular ecosystem, interaction or resource. Unfortunately, the hour on forests is less successful than the other episodes: It jumps abruptly from Ecuador to Indonesia and back again. In the rush, important questions end up unanswered. How do humans in the Amazon rainforest sustain their hunter-gatherer lifestyle? How do trained elephant squads help prevent wild elephants from eating farmers’ crops in Sumatra? There are many stories of human-ecosystem interactions to tell, but the episode might have worked better with fewer stories and more answers.

The narrative through the rest of the episodes is significantly smoother. The tone of the program is hopeful and often deeply affecting. It’s hard not to get a little emotional when Sanjayan shows one of the first releases of a captive-bred panda into the wild.

The program highlights that humans, under the right conditions, can live in harmony with and even help an ecosystem, rather than destroy it. The documentary also features the stunning wildlife footage without which any nature show would be incomplete.

The documentary series is an interesting and inspiring introduction to how people live in, and just not off, their environments. As Sanjayan notes, preserving our wild places is our responsibility: “We humans are not separate from nature. We are part of it.” — *Bethany Brookshire*



M. Sanjayan, host of *Earth: A New Wild*, seeks examples in which people and wildlife interact in positive ways.

FROM TOP: COURTESY OF ANNA MCVEY; COURTESY OF AMI VITALE

BOOKSHELF

Island on Fire

Alexandra Witze and Jeff Kanipe

In the last five years, volcanic eruptions in Iceland have disrupted air travel twice, triggering the cancellation of thousands of flights and causing billions of dollars of losses to airlines.

But those geophysical flare-ups are brief whiffs compared with past eruptions on the island: Starting in June 1783, one of the largest lava flows in modern times spilled from a 27-kilometer-long volcanic fissure called Laki in southern Iceland.

In *Island on Fire*, science writers Kanipe and Witze, the latter of whom is a contributing correspondent for *Science News*, recount that fateful eight-month-long eruption. They also explain why Iceland has so many dangerous volcanoes that are well-placed to play havoc with regional and global climate, not to mention modern air travel (*SN Online: 6/19/12*).

Deftly interweaving information compiled by naturalists and astronomers of the day (and even Benjamin Franklin, who was in Paris during the eruption) with interviews with modern-day scientists and historians, the authors provide a captivating overview of an eruption that killed few people directly. But famine and other long-term effects probably took the lives of one-fifth of Iceland's residents and half of its livestock.

Breathing problems caused by the sulfurous haze that wafted from Laki to Europe may have contributed to the early deaths of tens of thousands. People also starved because the sulfur dioxide in the air produced acid rain, which blighted the continent's crops. Other Europeans froze to death during the bitter, volcano-cooled winter that followed.

Laki's eruption influenced life across a large swath of the Northern Hemisphere, and it — or one of its Icelandic kin — will undoubtedly do so again. But the next time, Witze and Kanipe note, a massive eruption could impose far higher costs on a world that's deeply dependent upon air transport and far more interconnected today than it was in the 18th century. — *Sid Perkins*

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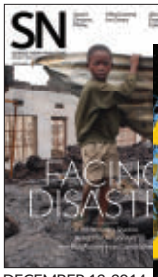

DECEMBER 13, 2014

DECEMBER 27, 2014

SOCIAL MEDIA

Readers' favorite stories of 2014

On Twitter, we asked readers which of our Top 25 stories were their favorites. Ebola claimed the No. 1 spot on our list, but the Rosetta mission and the drawbacks of artificial sweeteners proved popular online.

"Gut reacts to artificial sweeteners. Once again, we are reminded that there are no shortcuts."
@MedWriterBliss

"Rosetta has to be #1 for the complexity of the entire mission."
@Paulsenlaw

"Dust in the galaxy masquerading as ripples in space!? Definitely that one!"
@Kristie_Ray_

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Odor confusion

People just aren't very good at putting names to smells. It turns out that the odor-to-language interface in the brain may be less efficient than the sophisticated neural circuitry that processes visual and auditory information, as ***Rachel Ehrenberg*** *reported in "Brain regions link odors to words"* (SN: 12/13/14, p. 8).

"Imagine my surprise when I read your short article on how the brain links words to odors," wrote **Tim Geho**. "It states that 'people have a hard time identifying odors.' Just the very day before, I read ... that instead of the long-held belief that people can distinguish about 10,000 scents, it is now thought that the average person can detect at least a trillion different smells. These two articles seem to reach vastly different conclusions."

The two studies were examining separate things, explains **Ehrenberg**. The "trillion different smells" study (*SN: 12/27/14, p. 25*) concluded that humans can discriminate between lots of odor pairs — basically, it showed that people have a good sense of smell. The brain regions study, however, looked at people's ability to name odors. The authors were trying to figure out why humans are so bad at describing odors in words, even though they're good at telling smells apart. The research suggests that neural information about odors is still pretty crude when it reaches the brain's language network, so people depend more on context to describe what they smell.

Stem cells stalled out

Two papers detailing a simple method for making stem cells were retracted last year when other researchers were unable to replicate the results. ***Tina Hesman Saey*** *summed up the controversy in "Easy stem cells a no go"* (SN: 12/27/14, p. 25) *as part of* Science News' *Top 25 stories of the year.*

Some readers felt that *Nature*, the journal that published the now-retracted papers, deserved a share of the blame. "It was reported that the peer reviewers did not recommend publication because of 'grave concerns over the work,' but it was published anyway. *Nature* is now trying to spin the controversy as something that could not have been spotted prior to publication despite its own peer reviewers being on record as having rejected it," wrote commenter **wooter**. "Perhaps the editors at *Nature* need to reevaluate their motivation regarding the publication of papers that promote something that appears to be too good to be true, because it may just turn out to be the case."

Commenter **Physics Police**, however, came to the journal's defense. "Let's be careful in how we criticize *Nature*. They clearly blew this one. But just because some reviewers had some negative feedback doesn't mean a paper should go unpublished. We don't know the full story about how this paper was reviewed. For a hypothetical example, some 'grave concerns' might go away with a revision that includes missing data tables. Remember that fraud and scientific misconduct are often invisible to the reader."

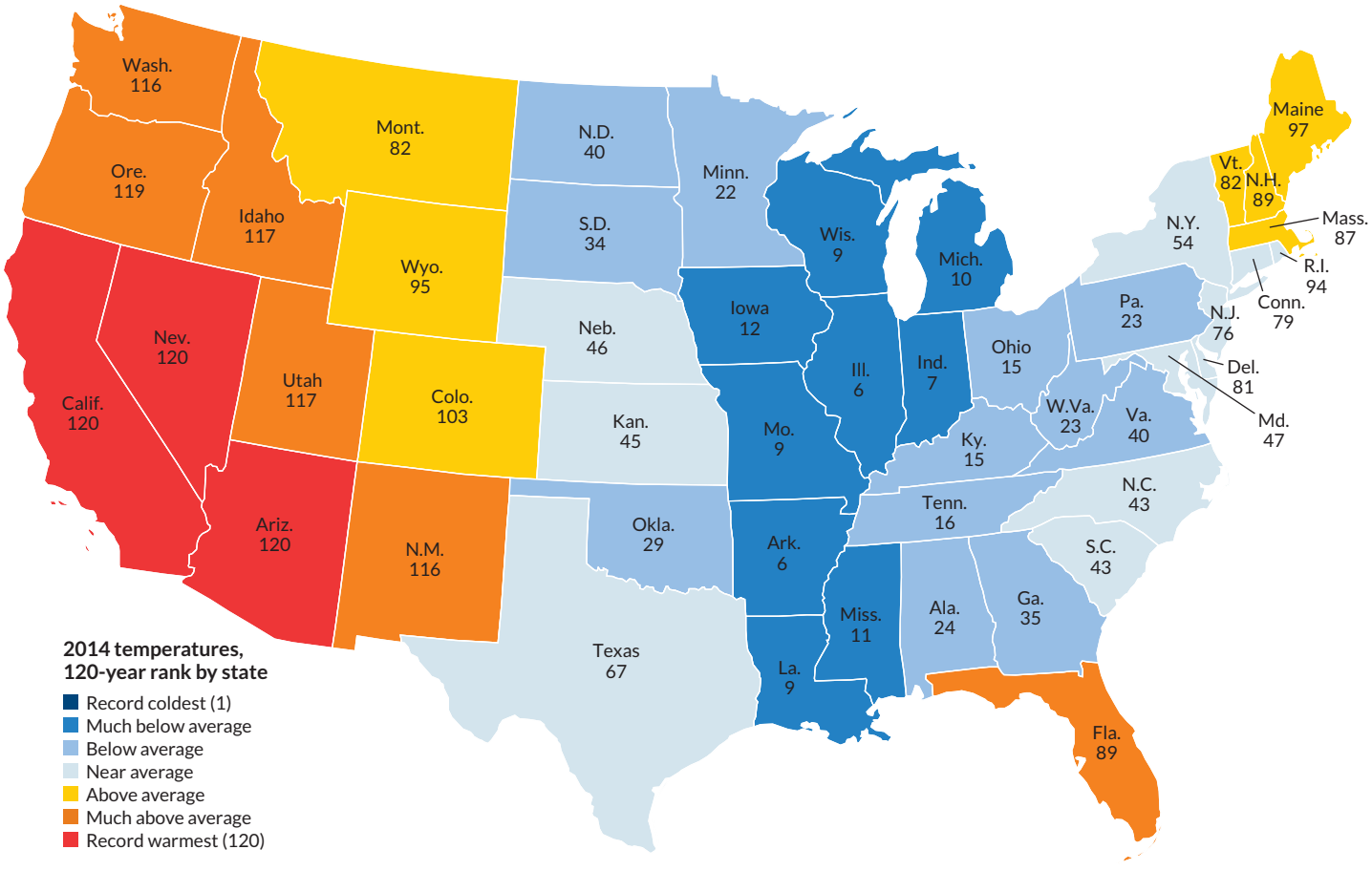
Support for *SN*

Long-time reader **Paul Ebel** wrote in with some kind words for *Science News*. "I have been a subscriber of *SN* for more than 20 years and have bought subscriptions for my grandchildren and for my business partners. I think this magazine is one of the most important ways to vet news about science," he said. "Thanks for all that you do. In particular, thank Ms. Emerson for her notes on the second page. I always read every word she writes, and that sets the stage for the evening of enjoying the magazine."

Corrections

The magnitude 5.7 earthquake that rattled Oklahoma in 2011 is attributed to the Wiltzetta Fault in "Carbon quakes" (*SN: 1/24/15, p. 14*). The correct spelling of the fault's name is Wilzetta.

On Page 15 of the same feature, the wrong issue date is provided for an earlier *Science News* story. That story can be found at *SN: 9/8/12, p. 20*.



The continental divide of 2014 temperature

While last year was the hottest on record worldwide, the contiguous United States experienced extremes on both ends of the thermometer.

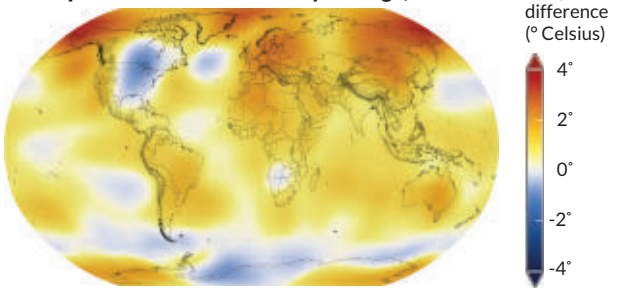
Arizona, California and Nevada notched their highest annual temperatures since record keeping began in 1895, the National Oceanic and Atmospheric Administration reported on January 12. (A 1 on the map represents a state's coldest year in 120 years; 120 represents its hottest.) Four days later, NASA and NOAA revealed that 2014 was Earth's warmest year since 1880 (see inset). Yet nine states extending south from the Great Lakes to the Gulf of Mexico experienced the opposite, reporting a year among the top 12 coldest.

The country's thermal divide stemmed primarily from the polar jet stream, a strong high-altitude air current usually situated over the Arctic. During early 2014, the jet stream frequently dipped far southward over the nation's midsection, delivering brutal cold to the Midwest while leaving the western United States (including Alaska, which had its hottest recorded year) uncommonly warm and dry.

California surpassed its previous annual record high by a full degree Celsius, which exacerbated the state's ongoing drought (*SN: 1/10/15, p. 16*). Seven additional western states sweated through one of their five warmest years on record, according to the Jan. 12 report.

Overall, the continental United States had an average temperature of 11.44° C (52.59° Fahrenheit) in 2014, which ties 1977 for the 34th warmest ever recorded. Despite the early-year cold spell, 2014 marked the 18th consecutive year that the temperature exceeded the 20th century annual average of 11.17° C. — *Thomas Sumner*

Departure from 20th century average, 2014



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We found our most important watch in a soldier's pocket

It's the summer of 1944 and a weathered U.S. sergeant is walking in Rome only days after the Allied Liberation. There is a joyous mood in the streets and this tough soldier wants to remember this day. He's only weeks away from returning home. He finds an interesting timepiece in a store just off the Via Veneto and he decides to splurge a little on this memento. He loved the way it felt in his hand, and the complex movement inside the case intrigued him. He really liked the hunter's back that opened to a secret compartment. He thought that he could squeeze a picture of his wife and new daughter in the case back. He wrote home that now he could count the hours until he returned to the States. This watch went on to survive some harrowing flights in a B-24 bomber and somehow made it back to the U.S. Besides the Purple Heart and the Bronze Star, my father cherished this watch because it was a reminder of the best part of the war for anysoldier—the homecoming.

He nicknamed the watch *Ritorno* for homecoming, and the rare heirloom is now valued at $42,000 according to *The Complete Guide to Watches*. But to our family, it is just a reminder that nothing is more beautiful than the smile of a healthy returning GI.

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