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NOVEMBER 11, 2017

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# Tangled Paths

Species are not as distinct as textbooks would have us believe

VOL. 192 | NO. 8

# ScienceNews

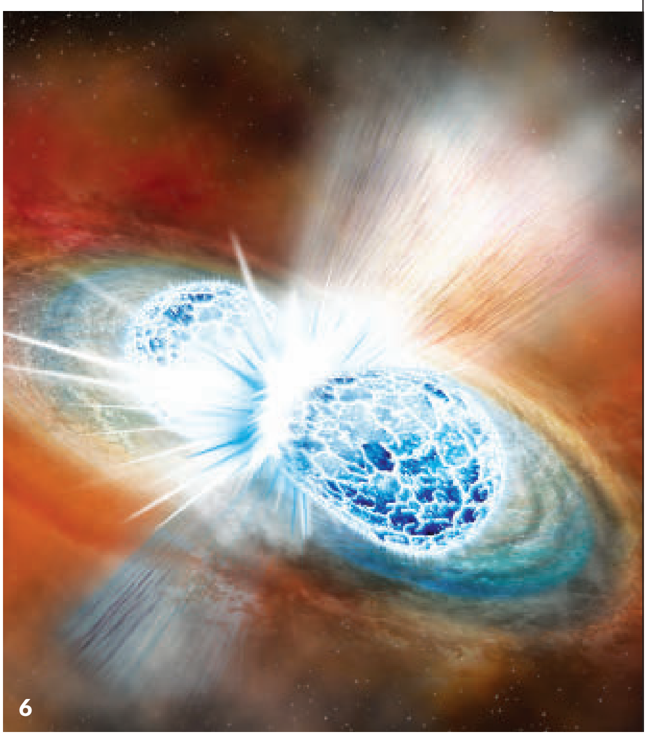
22

## Special Report



## News





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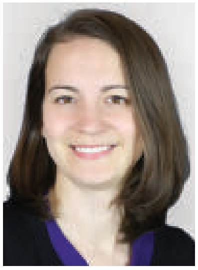
## Departments



**COVER** The tree of life takes plenty of twists and turns. Species swap DNA and split in unexpected ways. *Nicolle Rager Fuller*

CLOCKWISE FROM TOP: NICOLLE RAGER FULLER; STOCKTREK IMAGES INC./ALAMY; ROBIN DIENEL, COURTESY OF CARNEGIE INSTITUTION FOR SCIENCE



# Great praise for categories, and seeing beyond them

Classification is inevitable. It's a widespread human tendency and a bedrock of scientific study. From rocks to stars to the stinkbug buzzing against my window, from parts of speech to diseases to the fundamental forces of nature, if an object or phenomenon can be described, it will be grouped with others like it and distinguished from those that differ.

One of the best-known scientific classifiers was, of course, Carl Linnaeus, the father of taxonomy. In his *Systema Naturae*, published in the 18th century, Linnaeus attempted to develop a scheme that could reveal the divine order in creation. Though he was not the first to label organisms by species and genus, Linnaeus consistently used binomial nomenclature and grouped genera into higher taxa according to shared features. Scientists still use some of the basics of this system today.

The benefits of this classification system are enormous. The scheme guides researchers in giving newly discovered organisms names. Those names provide a shared language so scientists can communicate what they are studying and what they've learned, allowing knowledge to build over time. Grouping organisms also helps researchers recognize patterns. Biologists can thus study not only how a single lineage evolved, but also the fundamentals of evolution itself. They can ask how organisms are related, how environments shape organisms and other grand questions, such as what are the origins of life? Similar praise can be showered on other classification schemes. By arranging the elements according to their properties on a periodic table, for example, Dmitri Mendeleev and others were able to predict undiscovered elements.

Yet categorical perfection is challenging, and pitfalls abound — including in the most modern systems. On Page 16 of this issue, Tina Hesman Saey describes how species don't always stay in the boxes that scientists assign. There's a fair amount of interbreeding, especially within microbes and plants, and we know that human ancestors shared DNA across species lines (see Page 10). In an accompanying essay on Page 22, Susan Milius directly tackles the troubles with defining the term "species," one of biology's richest categories. The term even frustrated Charles Darwin, who in *On the Origin of Species* wrote, "I was much struck how entirely vague and arbitrary is the distinction between species and varieties."

Classification can also impede our understanding. In the 18th century, French astronomer Charles Messier began compiling a list of "nebulae." His original goal was to distinguish these fuzzy blobs of light in the sky from comets that come and go. But by putting these blobs all in one box, astronomers failed to realize that the blobs aren't all the same kind of thing. As data came in, opinion swung back and forth between nebulae as clouds of gas or groupings of stars. It wasn't until the 20th century that Edwin Hubble confirmed that, though some nebulae are gas clouds and some are star groups within our galaxy, others are galaxies outside the Milky Way — their own "island universes." (For the origin of that phrase, check out bit.ly/SN_islanduniverse.)

There's a lesson here that spans the sciences, and perhaps the rest of life: Boxes are helpful, but they can also blind us. — *Elizabeth Quill, Acting Editor in Chief*





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SSP

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Excerpt from the November 11, 1967 issue of *Science News*

50 YEARS AGO

## Fungus farmers

Finding the chemical basis for the close association between the Attine ants, inhabiting an area extending from Argentina to the southern United States, and the fungus they culture is the aim of research ... by Prof. Michael M. Martin of the University of Michigan. Although many animals feed on fungi, the culturing of fungus by the Attine ants is the only known example of creatures growing their own.

**UPDATE:** Attine ants, a group of more than 200 species, began cultivating fungus "gardens" for food around 60 million years ago. Total codependence between the ants and fungi evolved around 30 million years ago, scientists wrote in April in *Proceedings of the Royal Society B*. During a global shift to a more arid climate with long seasonal dry periods, the moisture-loving fungi may have had a harder time surviving outside of ant-tended plots. Ants also became more dependent on fungi, losing, among other things, the ability to produce the amino acid arginine.

SOAPBOX

## For trauma surgeon, gun violence is personal

Joseph Sakran knows more about the horrific impact of firearm-related injuries than the average trauma surgeon. A bullet nearly killed him 23 years ago. He was 17. At his high school's season-opening football game, a fight broke out and someone fired into the crowd.

"A .38-caliber bullet ripped through my throat and ended up in my shoulder," he says. He had multiple surgeries and spent six months with a breathing tube in his windpipe. His recovery kept him home for most of his senior year. He still has a paralyzed vocal cord, which leaves his voice raspy at times.

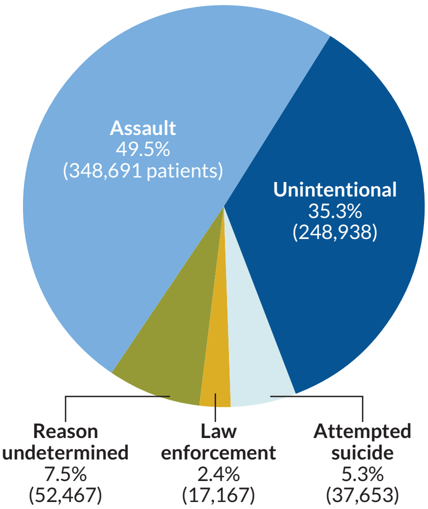
The experience inspired Sakran to become a surgeon, and it compelled him to work at the intersection of medicine, public health and public policy. His goal: "to reduce gun violence in our communities across this country."

One way to do that is with data. Sakran and his colleagues at Johns Hopkins University School of Medicine looked at data from more than 900 U.S. hospitals from 2006 to 2014 and estimated that, nationwide, almost 705,000 people landed in an emergency department with a gun-related injury. Nearly half of victims were shot in an assault, 35 percent were shot unintentionally and 5 percent had attempted suicide. Gun-related ER visits and hospital stays cost about $2.8 billion annually, the researchers estimate in the October *Health Affairs*.

Such evidence is needed to tailor interventions "that will help minimize this public health crisis that we're facing," Sakran says, and he'd like to see a lot more research on the causes and costs of gun violence. One roadblock is Congress, which has severely limited federal funding to study gun violence (*SN: 5/14/16, p. 16*). "Why wouldn't we want to know what the truth is and what the data show?" he asks. "Let's look at it, let's study it, let's figure out where we can make improvements. Everyone should want that."

When he was shot, Sakran says he felt numb. "Everything felt like it was going in slow motion." Now director of emergency general surgery, he operates on people who come into the ER with gunshot wounds. "The moment that is most difficult for me is when I have to go out to the waiting room and talk to families," Sakran says. "I sometimes think of my own parents and what they must have been going through when the trauma surgeon came out to talk to them."
— *Aimee Cunningham*

**Gun injury causes** U.S. firearm-related injuries, estimated from 2006 to 2014, were mainly due to assaults or accidents. For all categories but suicide, young adults ages 18 to 29 bear the brunt of the injuries. Suicide attempts using guns affect adults of all ages almost equally. SOURCE: F. GANI, J. SAKRAN AND J. CANNER/ *HEALTH AFFAIRS* 2017




FROM TOP: CLEANFOTOS/SHUTTERSTOCK; C.CHANG

New synthetic skins inflate into 3-D shapes, such as this succulent bloom, and flatten back into 2-D sheets in just seconds.

TEASER

## Shape-shifting skin

Now you see it, now you don't. Inspired by octopuses and other cephalopods that change their skin textures for camouflage, researchers created a stretchy material that inflates into various 3-D shapes and quickly flattens back out. These camouflaging "skins," described in the Oct. 13 *Science*, may someday help robots covertly observe animals in their natural habitats or provide cover for military operations in hostile territory.

The new material is modeled after papillae — the tiny bumps that cephalopods raise and lower on their skin to mimic coral, seaweed and other textures in their surroundings, says study coauthor James Pikul, an engineer at the University of Pennsylvania. Each whoopee cushion–shaped pad of synthetic skin is made of silicone rubber with a pattern of stiff, fabriclike mesh on top. With a pump of air, the silicone stretches but the fibrous material doesn't, allowing the skin to form a particular shape.

By changing the layout of the mesh, the engineers fabricated skins that assumed the form of a succulent or matched the shape of surrounding stones in a rock bed. — *Maria Temming*

FROM TOP: J.H. PIKUL ET AL/*SCIENCE* 2017; STOCKTREK IMAGES INC./ALAMY

SCIENCE STATS

## Obesity in kids is on the rise globally

Over the last 40 years, the number of children and teens with obesity has skyrocketed worldwide to an estimated 124 million, up tenfold for girls and more than 12-fold for boys, researchers report online October 10 in the *Lancet.* Using body mass index, a ratio of weight to height, of more than 30 million 5- to 19-year-olds around the world, researchers tracked trends in obesity, defined as a BMI of about 19 or higher for a 5-year-old and 30 or higher for a 19-year-old. The authors estimate that roughly 15 percent of the rise in obesity prevalence from 1975 to 2016 was due to population growth.

**Number of boys with obesity, 5–19 years old**

| 1975 | 2016 |
|---|---|
| 6 million | 74 million |

**Number of girls with obesity, 5–19 years old**

| 1975 | 2016 |
|---|---|
| 5 million | 50 million |

Even more kids and teens — about 117 million boys and 75 million girls — were moderately or severely underweight in 2016. But the total number of obese children is expected to overtake those numbers by 2022, the researchers say. Globalization of poor diet and inactivity are partly to blame, says William Dietz, a pediatrician at George Washington University in Washington, D.C., who wrote a commentary in the *Lancet*. — *Aimee Cunningham*

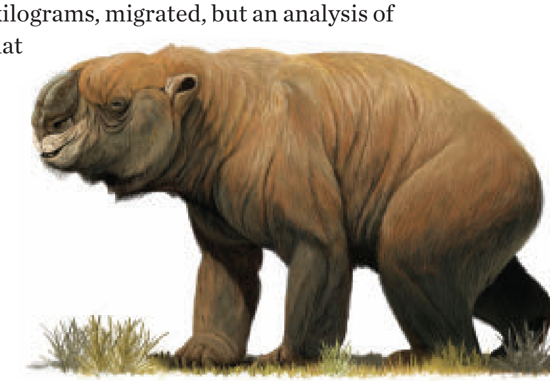
FIRST

## This massive ancient marsupial migrated

The largest marsupial to ever walk the Earth is also the only marsupial known to have ever migrated seasonally. *Diprotodon optatum* was a gigantic wombat-like herbivore that lived in what's now Australia and New Guinea during the Pleistocene Epoch, until it died out about 40,000 years ago. A new analysis of an ancient tooth suggests that the marsupial went on long, seasonal migrations.

Animals pick up the chemical element strontium through their diet, and it leaves a record in their teeth. The ratio of different strontium isotopes varies from place to place, providing clues to where an animal lived. Strontium isotope ratios in a *D. optatum* incisor revealed a repeating pattern. The finding suggests the animal, with teeth that wore down and grew throughout its life, migrated seasonally. And the animals generally visited the same rest stops each year, researchers report September 26 in *Proceedings of the Royal Society B.*

This finding is the first evidence of a marsupial — living or extinct —making round trip migrations, says study coauthor Gilbert Price, a paleoecologist at the University of Queensland in Brisbane, Australia. It's not clear why this mega-marsupial, which weighed up to 2,800 kilograms, migrated, but an analysis of carbon isotopes in the tooth suggests that *D. optatum* ate a fairly limited diet. So the creature might have followed food sources that popped up seasonally in different places, the authors propose. — *Laurel Hamers*



A new analysis suggests that *Diprotodon optatum*, a giant plant-eating marsupial that went extinct about 40,000 years ago, migrated long distances, much like today's zebras and wildebeests.

Watch a video of a shape-shifting material at **bit.ly/SN_3Dskin**


After two neutron stars slammed together, as shown in this artist's conception, scientists detected gravitational waves, a burst of gamma rays and a glow from ejected material.

ATOM & COSMOS

# Neutron star crash seen for first time

## Gravitational waves help reveal where heavy elements form

**BY EMILY CONOVER**

**WASHINGTON —** Two ultradense cores of dead stars have produced a long-awaited cosmic collision, showering scientists with riches.

The event was the first direct sighting of a smashup of neutron stars, which form when aging stars explode and leave behind a neutron-rich remnant. In the wake of the collision, the churning residue forged gold, silver, platinum and a smattering of other heavy elements such as uranium, researchers reported October 16 at a news conference. Such elements' birthplaces were previously unknown, but the origins were revealed by the cataclysm's afterglow.

"It really is the last missing piece" of the periodic table, says Anna Frebel, an astronomer at MIT who was not involved in the research. "This is heaven for anyone working in the field." After the collision, about 10 to 100 times the Earth's mass in gold was spewed out into space, scientists calculated.

Using data from about 70 observatories, astronomers characterized the event in exquisite detail, describing the results in a slew of papers published in *Science, Nature, Physical Review Letters* and other journals. A tremor of gravitational waves, spotted by the Advanced Laser Interferometer Gravitational-Wave Observatory, LIGO, on August 17, provided the first sign of the cataclysm.

A sequence of various types of electromagnetic radiation followed that gravitational trill, like musical instruments taking turns in a symphony. A burst of gamma rays segued into a glow of visible and infrared light, first spotted about 11 to 12 hours after the smashup. Over a week later, as those wavelengths faded, X-rays crescendoed, followed by radio waves.

Combining gravitational waves with light from a neutron star merger is a long-held dream of astrophysicists. "The picture that you can put together by having all of those sources is synergistic," says LIGO spokesperson David Shoemaker, a physicist at MIT. "You can make inferences that otherwise would be impossible."

That detailed picture revealed the inner workings of neutron star collisions and the source of brief blasts of high-energy light called short gamma-ray bursts. Scientists also made a new calculation of how fast the universe is expanding.

LIGO's two detectors, in Louisiana and Washington state, registered an unmistakable sign of the upheaval: A shimmying of space itself that continued for about 100 seconds. It was the strongest and longest series of spacetime ripples LIGO has ever seen. Scientists knew they had something big, says LIGO member Vicky Kalogera, an astrophysicist at Northwestern University in Evanston, Ill. "The e-mails that were circulated said, 'Oh my God, this is it.'"

That vibration was an indication of a cosmic crash: Whirling round each other as if on an ill-fated merry-go-round, two orbiting neutron stars spiraled closer and closer until they converged. The neutron stars, whose masses were each 1.17 to 1.60 times that of the sun, probably collapsed into a black hole, though LIGO scientists could not confirm the stars' fate. LIGO has previously spotted mergers of black holes with masses tens of times that of the sun; the smaller masses of the orbiting duo pointed the finger at neutron stars. And because merging black holes aren't expected to emit light, the fireworks show that followed solidified the case.

LIGO's sister experiment in Italy, Advanced Virgo, saw only a faint signal. That relatively weak detection helped narrow down where the convulsion occurred to "a part of the sky that was a blind spot of Virgo," Kalogera says. That constrained the site to within a region of 28 square degrees in the southern sky.

Just 1.7 seconds after the gravitational wave signal, NASA's Fermi space telescope spotted a glimmer of gamma rays in the same neighborhood of the sky. Meanwhile, other telescopes swung into action, picking up a glow of visible light where none had been before. "We saw what looked like a new star," says astronomer Edo Berger of Harvard University, who led a team that spotted the light with the Dark Energy Camera on the Blanco telescope in Chile. That detection pinpointed the galaxy NGC 4993, 130 million light-years from Earth in the constellation Hydra, as the collision site.

That afterglow also revealed a story of stellar alchemy: With the stars' deaths came the birth of elements. As the crash

ROBIN DIENEL, COURTESY OF CARNEGIE INSTITUTION FOR SCIENCE spurted neutron star material into space, a bevy of heavy elements formed through a chain of reactions called the r-process (*SN: 5/14/16, p. 9*). In this process, which requires a neutron-rich environment, atomic nuclei rapidly gobble up neutrons and decay radioactively, thereby transforming into new elements, before resuming the neutron gorgefest. The r-process is thought to produce about half of the elements heavier than iron.

Scientists detected the characteristic glow of this process, called a kilonova, in follow-up observations. "Until this event, we had never directly seen anywhere in nature these heavy elements being forged," says Brian Metzger, a theoretical astrophysicist at Columbia University.

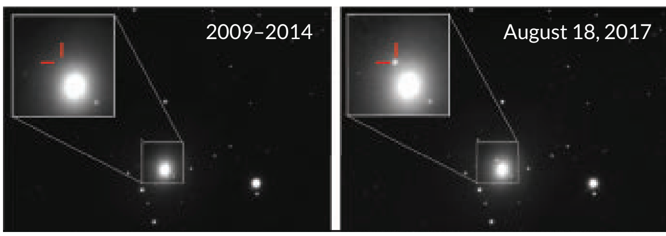
Previously, astrophysicists disagreed about where the r-process occurs: Two top candidates were exploding stars called supernovas and neutron star mergers. Although scientists can't yet say whether all r-process elements are produced in neutron star mergers, the amount such collisions should produce appears large enough to explain the abundances found in the universe.

Additional riches were revealed by gamma rays. Such short gamma-ray bursts appear in the sky about 50 times a year. But finding their source is "a long-standing problem," says theoretical astrophysicist Rosalba Perna of Stony Brook University in New York. The detection clinched it: Short gamma-ray bursts come from neutron star tête-à-têtes.

The neutron stars' union also gave researchers the opportunity to gauge the universe's expansion rate, by measuring the distance of the collision using gravitational waves and comparing that with how much the expansion stretched light from the galaxy. Scientists have previously measured this property, known as the Hubble constant, through other means. But those measurements are in disagreement (*SN: 8/6/16, p. 10*).

The new measurement indicates that distantly separated galaxies are spreading apart at about 70 kilometers per second for each megaparsec (about 3.3 million light-years) between them. That estimate falls between the previous two: 67 and 73 km/s per megaparsec. Future mergers could improve the measurement.

"These are all just unbelievable, major advances," says LIGO member Daniel Holz, an astrophysicist at the University of Chicago. "It's really been this insane thrill." ■




Gravitational waves indicated where two neutron stars had collided, then telescopes saw a spot of light (right, red lines) where none had been before (left).

P.K. BLANCHARD, E. BERGER, PAN-STARRS, DECAM

MATH & TECHNOLOGY

# Nanoparticles disarm superbugs

## Quantum dots help make bacteria vulnerable to drugs

**BY MARIA TEMMING**

Antibiotics may have a new partner in the fight against drug-resistant infections.

Researchers have engineered nanoparticles to produce chemicals that render bacteria more vulnerable to antibiotics. These quantum dots, described October 4 in *Science Advances*, could help combat pathogens that have developed resistance to antibiotics.

"Various superbugs are evolving too rapidly to be counteracted by traditional drugs," says Zhengtao Deng, a chemist at Nanjing University in China. "Drug-resistant infections will kill an extra 10 million people a year worldwide by 2050 unless action is taken."

In the study, antibiotics spiked with quantum dots fought off bacteria grown in the lab as effectively as 1,000 times as much antibiotic alone. That's "really impressive," says Chao Zhong, a materials scientist at ShanghaiTech University. "This is a really comprehensive study."

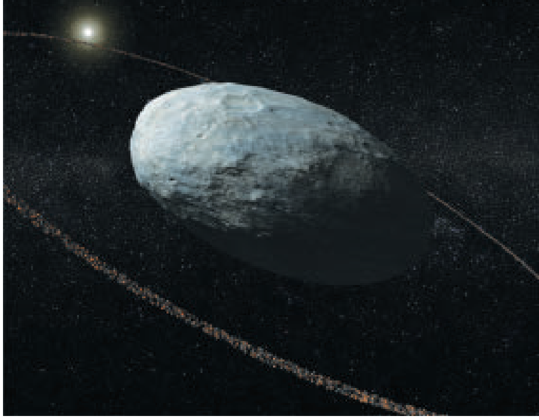
Quantum dots, previously investigated as a tool to trace drug delivery throughout the body or to take snapshots of cells, are made of semiconductors (*SN: 7/11/15, p. 22*) — the same kind of material in electronics such as laptops and cell phones. The new quantum dots are tiny chunks of cadmium telluride just 3 nanometers across, or about as wide as a strand of DNA.

When illuminated by a specific frequency of green light, the nanoparticles' electrons can pop off and glom on to nearby oxygen molecules — which are dissolved in water throughout the body — to create a chemical called superoxide. When a bacterial cell absorbs this superoxide, it throws the microbe's internal chemistry so off-balance that the pathogen can't defend itself against antibiotics, explains study coauthor Anushree Chatterjee, a chemical engineer at the University of Colorado Boulder.

Chatterjee and colleagues mixed various concentrations of quantum dots into different concentrations of each of five antibiotics, then added these concoctions to samples of four drug-resistant bacterial strains, including a strain of *Salmonella*. More than 75 percent of the 271 tested antibiotic and quantum dot combinations were better at killing or curbing the growth of bacteria than antibiotics would have been alone.

One limitation of this potential treatment is that this green light can activate the nanoparticles only mere millimeters under skin, says study coauthor Prashant Nagpal, a chemical engineer also at the University of Colorado Boulder. So these quantum dots could probably be used to treat only skin or accessible wound infections.

The researchers are now designing nanoparticles that absorb infrared light, which can pass through the body. "That could be really effective in deep tissue and bone infections," Nagpal says. ■



Haumea's ring, shown in this artist's illustration, revealed itself by momentarily blocking the light of a distant star.

ATOM & COSMOS

# Ring runs around oddball dwarf planet

## Haumea proves that debris circles can form beyond Neptune

**BY LISA GROSSMAN**

Haumea can do the hula-hoop. The egg-shaped dwarf planet is the first object beyond Neptune to be spotted sporting a ring of particles.

"It now appears that rings can be common in the outer solar system," says Jose-Luis Ortiz of the Institute of Astrophysics of Andalusia in Granada, Spain.

On January 21, Ortiz and colleagues used 12 telescopes at 10 observatories to peer into the Kuiper Belt, a region of icy objects beyond the orbit of Neptune, and watch Haumea block the light of a distant star. That tiny eclipse let the team measure the dwarf planet's size, shape and surrounding environment more accurately than ever before.

Haumea turned out to be larger — its long axis stretches at least 2,322 kilometers, a bit more than half the width of the contiguous United States — and less dense than previously thought, the team reports in the Oct. 12 *Nature*. To their surprise, the researchers also saw the background star flicker before and after its light was blocked by Haumea. That flicker is consistent with a 70-kilometer-wide ring around the dwarf planet.

The ring, probably made of rock and water ice, could be debris kicked up by impacts from small space rocks, Ortiz says. Or Haumea's unusually fast twirling — it completes a rotation every 3.9 hours — could fling particles into orbit.

Until recently, the only solar system bodies known to have rings were the giant planets: Jupiter, Saturn, Uranus and Neptune. Then in 2014 and 2015, astronomers spotted rings around the planetoids 10199 Chariklo and 2060 Chiron, suggesting that small bodies could hold on to rings, too.

Both of those small worlds are centaurs, objects whose orbits take them between Jupiter and Neptune, though centaurs may be interlopers from the more distant Kuiper Belt. Since recent searches for rings around Pluto came up empty (*SN: 10/28/17, p. 15*), no object farther away than Neptune seemed to have rings. Some astronomers speculated that something about the Kuiper Belt disrupted rings around small worlds there, or that the centaurs got their rings as part of the process that kicked the objects into their current orbits. Haumea's ring suggests that such structures can form and survive at the solar system's fringes after all.

"This discovery does disrupt that tidy narrative," says Matthew Tiscareno of the SETI Institute in Mountain View, Calif., who studies Saturn's rings. "Reality is more complicated — that is, interesting." ■

MATH & TECHNOLOGY

# New atomic clock is most precise yet

## Timepiece still needs to be tested for long-term accuracy

**BY MARIA TEMMING**

A new model of atomic clock is now the world's steadiest metronome, with a tick rate about six times as precise as the previous record-holder.

This souped-up clock is an optical lattice; it measures time by counting the oscillations of light in a laser beam, which happen about 430 trillion times per second. Strontium atoms in the clock tick off each oscillation by absorbing and reemitting this light.

Previous optical lattices held strontium atoms in a queue of pancake-shaped gas clouds, where atoms were liable to bump into each other, which could make them lose their rhythm (*SN: 10/22/11, p. 22*). That limited the precision of the clock's measurements.

In the new clock, described in the Oct. 6 *Science*, researchers assembled atoms in a gridlike structure — like eggs in egg cartons stacked on top of each other, says study coauthor Benjamin Bloom, a quantum engineer at Rigetti Computing in Berkeley, Calif. Thanks to weird laws of quantum mechanics, atoms locked in this rigid configuration can't jostle each other.

The arrangement helped to match the duration between each of the clock's ticks. After running the clock for an hour, the time between each tick lasted the exact same amount of time as the rest, give or take a couple quadrillionths of a second. The clock's predecessor could guarantee its ticks were identical only down to about 10 quadrillionths of a second (*SN: 5/16/15, p. 16*).

But just because the clock boasts extremely consistent ticks doesn't necessarily mean it doesn't tick too fast or too slow, says coauthor Jun Ye, a physicist at JILA, an institute jointly operated by the National Institute of Standards and Technology and the University of Colorado Boulder. To make sure this atomic clock keeps accurate time in the long run, Ye and colleagues must now compare it with other atomic clocks.

Extremely precise, accurate timekeeping can help scientists improve their definitions for standard units of measure. It can also help physicists spot incredibly small differences in how fast time elapses in various places, says Paul-Eric Pottie, a physicist at the Paris Observatory who was not involved in the study. This could help scientists catch gravitational waves rippling through space, since any variation could indicate that gravity is warping time differently in different spots. ■

BODY & BRAIN

# Flatworm gives clues to origins of pain

## Chemical middleman triggers ouch detectors, study suggests

**BY LAURA SANDERS**

Hydrogen peroxide, a molecule produced by cells under duress, may be a common danger signal, helping to alert animals to potential harm. New details from planarian flatworms of how this process works may deepen scientists' understanding of how people detect pain, and may ultimately point to better ways to curb it.

"Being able to get a big-picture view of how these systems are built and what they're cuing in on is always really helpful," says biologist Paul Garrity of Brandeis University in Waltham, Mass.

The results, published October 16 in *Nature Neuroscience*, center on the TRPA1 protein, a well-known pain detector in people. Embedded in the outside of some cells, TRPA1 helps many different animals detect harmful chemicals, physical injuries and extreme temperatures.

But TRPA1's seemingly inconsistent behavior has been puzzling. For instance, in *Caenorhabditis elegans* worms the protein is activated by cold. In mosquitoes, it's activated by heat.

Marco Gallio of Northwestern University in Evanston, Ill., and colleagues studied TRPA1 in the *Schmidtea mediterranea* flatworm. Normally, planarians avoid hot areas. But flatworms without the TRPA1 protein didn't shy away from parts of a chamber heated to 32° Celsius, the researchers found. And flatworms without TRPA1 seemed content to stay in a chamber laced with the compound that gives wasabi its kick. Those results suggest that TRPA1 is involved in planarians' responses to cellular danger.

In further tests, as the flatworms were heated to harmful temperatures, the flatworms' bodies produced more reactive oxygen species, chemicals that include hydrogen peroxide. Experiments with cells in dishes revealed that hydrogen peroxide directly activates planarian TRPA1.

Hydrogen peroxide, or other reactive oxygen species, may be universal danger signals that TRPA1 detects, Gallio and colleagues suspect. This general signal may explain a somewhat paradoxical property of TRPA1 that the researchers observed: Human TRPA1, which is activated by cold, allowed fruit flies to avoid hot areas, presumably by detecting hydrogen peroxide. The same was true for flatworm TRPA1, which doesn't directly respond to heat. That overlap in duty is possible because TRPA1 is responding to hydrogen peroxide, not temperature, the team proposes. With hydrogen peroxide as a middleman, TRPA1 can detect threats particular to different animals, Gallio says.

Studying TRPA1 in planarians offers insights about the evolutionary history of pain sensing. Because the planarian lineage split from those of flies and humans hundreds of millions of years ago, it's possible that a common ancestor possessed a hydrogen peroxide–sensing TRPA1 protein similar to planarians'. ■

GENES & CELLS

# Bird flu poses pandemic risk

## H7N9 strain can pass between lab animals through the air

**BY LAUREL HAMERS**

A new version of H7N9 avian influenza virus might be able to cause widespread infection and should be monitored, scientists say, although it currently doesn't appear to spread easily between people.

Researchers tested the virus and two genetically modified versions in ferrets, which are good models of how the flu might behave in people. The viruses spread to other ferrets through airborne fluid droplets like those released by a cough or a sneeze, sometimes turning deadly, the researchers report online October 19 in *Cell Host and Microbe*.

"This is an extremely well-done study," says John Lednicky, a virologist at the University of Florida in Gainesville. The findings link the behavior of the virus to its genetics — a key to understanding what makes a given virus dangerous and to monitoring its spread in a population.

H7N9 has circulated in China since at least 2013, killing 39 percent of the more than 1,500 people reported to have been infected as of mid-October. A recent mutation made H7N9 better able to replicate in birds and sicken them — which might affect its behavior in humans, too.

Pathologist Yoshihiro Kawaoka of the University of Wisconsin–Madison and colleagues took H7N9 from a person who died from this highly pathogenic version in 2016. The sample had two H7N9 varieties: A small genetic change had made one resistant to the antiflu drug Tamiflu.

Using the patient's virus, Kawaoka's group engineered two strains of highly pathogenic H7N9, one that was Tamiflu-resistant and one that wasn't. The team studied how those strains acted in ferrets compared with two other types: a less pathogenic one and the one from the 2016 patient. The 2016 virus and the Tamiflu-sensitive strain made ferrets sicker.

The team also paired sick ferrets with healthy ones, separating them with a barrier that allowed air to pass between cages. The ferrets had no direct contact, but the three highly pathogenic strains spread through the air via respiratory droplets. For example, the Tamiflu-sensitive strain infected three of four ferrets housed next to sick ones. Two died.

There's no cause for panic now, says Kawaoka, but H7N9 has many qualities, including its ability to spread through the air, that put it on a pandemic watch list.

Because ferrets were housed close together, the study can't say whether the virus can spread through the air over long distances, which would make the virus much more easily transmissible, Lednicky says. ■

GENES & CELLS

# Doubled-up DNA helps define humans

## Duplicate 'junk' regions may be involved in disease, study finds

**BY TINA HESMAN SAEY**

Doubling up on some DNA may have helped make humans human — and given us uniquely human diseases.

DNA that doesn't produce proteins may be especially important for creating differences between humans and other primates, biochemist Paulina Carmona-Mora reported October 18.

Carmona-Mora and colleagues in Megan Dennis' lab at the University of California, Davis identified parts of humans' entire set of genetic instructions, or genome, that are duplicated in people but not in other primates. Many of those regions overlap parts of the genome implicated in diseases and psychiatric disorders, Carmona-Mora said.

Researchers have found that some genes duplicated only in humans are involved in brain development and may account for humans' big brains (*SN: 3/21/15, p. 16*). Carmona-Mora concentrated on the space between genes — once considered "junk DNA" because it doesn't encode proteins. Far from being junk, this DNA is where molecular switches that help control gene activity are located. Carmona-Mora and colleagues found 80 regions where only humans have duplicated DNA. Each copy is 98 percent or more identical to the original. And some regions were copied more than once.

Such repetitive regions are usually ignored because they are difficult to tell apart, said Rajiv McCoy, an evolutionary geneticist at Princeton University. Carmona-Mora and colleagues have preliminary evidence that important biology goes on in those overlooked regions.

Within duplicate regions, the team discovered switches known as enhancers. Some of these enhancers appear to control genes both inside and outside the duplicated regions, either increasing or decreasing gene activity, Carmona-Mora said. Some of the enhancers are not present in the original copy or behave differently in duplicate regions.

For instance, the immune system gene *DUSP22A* on chromosome 6 was duplicated, but its copy, *DUSP22B*, is located on chromosome 16. Carmona-Mora found that many enhancers thought to control *DUSP22A*'s activity may actually govern the second copy. People can carry two to five copies. The consequences of having multiple copies are unknown.

Another doubled-up region has enhancers that turn on genes in the cerebellum, a part of the brain that, among other things, coordinates movement and speech. The researchers don't yet know all of the genes the enhancers control.

Some evidence hints that duplicate enhancers help control genes important in other parts of the brain. Deletions that remove some of these enhancers have been linked to schizophrenia, autism and other brain disorders, Carmona-Mora said. "What makes us human also makes us prone to disease."

The reason: Duplications can make the genome more fragile, McCoy said. Repetitive DNA can form loops that get cut out of the genome, removing the original DNA and the copies. ■

MEETING NOTES

### Neandertal mating returned lost DNA to humans

Mating with Neandertals restored some genetic heirlooms that *Homo sapiens* left behind in the exodus from Africa.

Those heirlooms are versions of genes, or alleles, that were present in humans' and Neandertals' shared ancestors. Neandertals carried many of those old alleles, passing them along generation after generation, while developing their own versions of other genes. A small number of humans left Africa around 100,000 years ago and settled in Asia and Europe. These migrants lost the ancestral alleles.

But when the migrants or their descendants interbred with Neandertals, Eurasians reinherited the ancestral heirlooms along with Neandertal DNA, John "Tony" Capra reported October 20. Present-day Europeans have over 47,000 of these reintroduced alleles; East Asians carry over 56,000, said Capra, of Vanderbilt University in Nashville.

Neandertal versions of genes may increase people's risk for some diseases (*SN: 3/5/16, p. 18*). Of the thousands of ancestral variants reintroduced into humans, only 41 have been linked to diseases, such as skin conditions and psychiatric disorders, Capra said. It's unclear whether the effect is from the ancestral variant or neighboring Neandertal DNA, but Neandertal DNA is more likely to blame. Many of the ancestral alleles are still in modern-day Africans, Capra said, "so they're unlikely to be very, very bad."
*— Tina Hesman Saey*

### Inbreeding reduces human fertility in offspring

Kissing cousins aren't doing their children any evolutionary favors, preliminary data suggest. Mating with a close relative reduces humans' evolutionary fitness — measured by the ability to produce offspring, David Clark of the University of Edinburgh reported October 20.

Offspring of second cousins or closer relatives make up about 10 percent of the world population, Clark said. He and colleagues calculated inbreeding's cost from data on over a million people from over 100 culturally diverse populations.

Compared with outbred peers, offspring of first cousins have 0.11 fewer children and are 1.6 times as likely to be childless. Childlessness was a result of fertility problems, not a lack of opportunity to have kids, Clark said. The more closely related the parents, the bigger the hit on reproductive fitness. Children of incest are four times as likely to be childless than outbred peers, Clark said. *— Tina Hesman Saey*

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BODY & BRAIN

# Zika epidemic ebbs but threat remains

## Herd immunity may be preventing more big outbreaks for now

**BY AIMEE CUNNINGHAM**

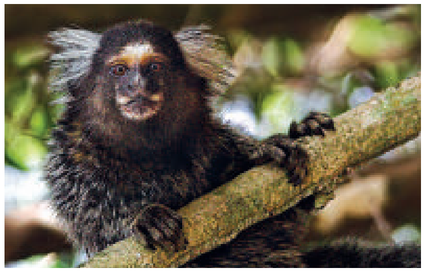
Less than a year after the World Health Organization declared Zika is no longer a public health emergency, the virus seems to have fallen from public consciousness, at least outside of heavily affected areas. The mosquito-borne virus staged a massive assault on the Western Hemisphere in 2015 and 2016 (*SN: 12/24/16, p. 19*), but this year, Zika appears to be in retreat.

In the hardest-hit countries, data from each country's department of health shows a striking drop in locally acquired cases, that is, ones caused by bites from local, infected mosquitoes. For instance:

- Brazil had over 216,000 probable cases in 2016; as of early September, the new cases for 2017 were around 15,500.
- Colombia tallied more than 106,000 suspected and confirmed cases from 2015 to the end of 2016. This year, new cases have plummeted, with around 1,700 by mid-October.
- Mexico went from about 8,500 confirmed cases in 2015 and 2016 combined to around 1,800 by early October of this year.

The numbers have also dropped in the United States and its territories. In Puerto Rico, Zika cases hit nearly 35,000 in 2016, the U.S. Centers for Disease Control and Prevention reports. But this year, less than 500 cases have been tallied as of mid-October. In the 50 states, the CDC counted about 5,100 cases in 2016. Most were in travelers who had been to places where Zika was active, although 224 were locally acquired in Florida and Texas. So far in 2017, only about 300 cases have been reported as of mid-October, mostly from travelers. Local transmission seems to have come to a standstill, with one suspected case in Texas and one case confirmed in Florida.

That doesn't mean Zika's days are numbered. If Zika behaves like other arboviruses, such as chikungunya and dengue, it will probably stick around. Arbovirus diseases tend to be cyclical, says public health researcher Ernesto Marques of the University of Pittsburgh. "You have big booms, then they drop. Then a few years later, they come back again."



The Zika virus epidemic in the Americas has waned, but the virus may be able to hide out in an animal reservoir, such as the common marmoset, between human outbreaks.

Why the dramatic rise and fall? The likely answer is herd immunity, says epidemiologist Albert Ko of the Yale School of Public Health. "Zika came in like a bulldozer," he says, and many people in the Americas who coexist with *Aedes* mosquitoes, which transmit Zika, were infected. Now, "there are so many people who've already been exposed to the virus and are presumably immune, it kind of protects indirectly the people who haven't been infected. So that's probably happened."

For every virus, a certain portion of the population has to be infected before herd immunity takes hold, says David Morens, senior scientific adviser to the director of the National Institute of Allergy and Infectious Diseases in Bethesda, Md. It depends on how transmissible the pathogen is. For example, the measles virus easily leaps from person-to-person, so at least 92 to 95 percent of a community must have immunity (typically through vaccination) to prevent outbreaks.

Zika virus transmission is more complicated since mosquitoes are involved, Morens says. Other factors such as how dense the human population is in an area, mosquito abundance and climate also play a part. "But it's clear there is some level of herd immunity," he adds. "We see it with all of these arboviruses that cause epidemics. They burn out because the virus can't find enough people to infect."

It's difficult to assess what percentages of populations across the Americas have been exposed to Zika. While the virus is linked to birth defects and to neurological problems in adults, most cases lead to mild or no symptoms. Some infected people probably don't get medical assistance, leading to missed cases. And diagnostic tests looking for antibodies against Zika can't always tell the difference between Zika and dengue infections.

It's also unclear for mosquito-borne diseases how widespread infection needs to be before herd immunity kicks in. Scott Weaver, a virologist at the University of Texas Medical Branch in Galveston, notes that in places where chikungunya immunity was measured, "typically from 20 to 50 percent of the population became infected as the outbreak swept through a given region." At those levels, "we don't see very efficient transmission."

Though the downtick in Zika cases is evidence of herd immunity, whether a person's past infection leads to lifelong immunity is unknown. The general understanding of Zika's close relative dengue is that, once someone has had an infection with one type of dengue virus, that person is protected from further infections from that type. But a 2016 study in the *Journal of Infectious Diseases* found reinfections are possible. So Zika immunity might wane over time, perhaps leading to reinfections, says pediatrician and microbiologist Peter Hotez of Baylor College of Medicine in Houston.

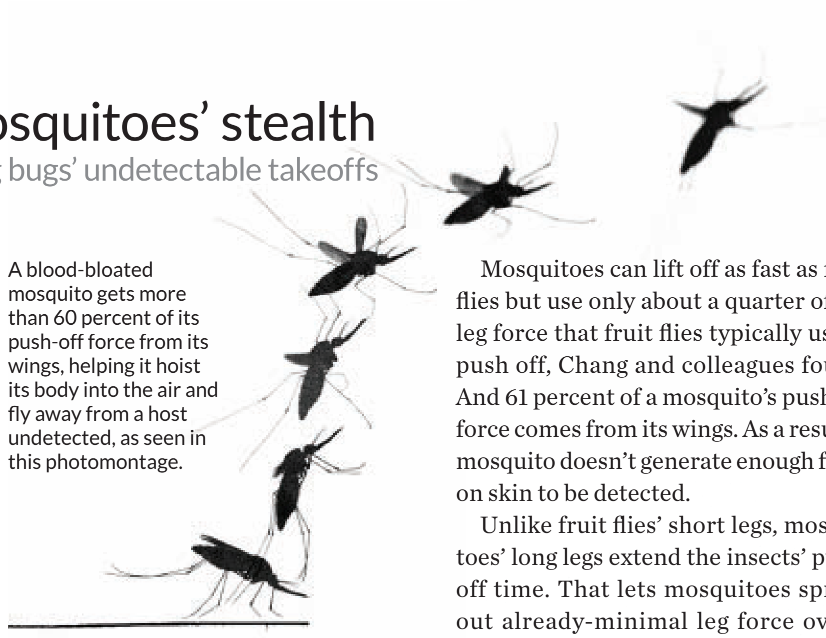
It's also possible that Zika will find an animal host in the Western Hemisphere, providing the virus a way station of sorts until the human population is more susceptible again. Researchers have detected Zika in capuchin monkeys and common marmosets, which both reside near humans in Brazil (*SN: 3/4/17, p. 15*).

All of the unknowns make it hard to predict when Zika will reemerge. There may be epidemics here and there, and then years later it pops up "in a place, in a time you can't predict," Morens says. "The Zika virus will be around indefinitely." ■

LIFE & EVOLUTION

# Physics explains mosquitoes' stealth

## Wings do the heavy lifting during bugs' undetectable takeoffs



A blood-bloated mosquito gets more than 60 percent of its push-off force from its wings, helping it hoist its body into the air and fly away from a host undetected, as seen in this photomontage.

**BY MARIAH QUINTANILLA**

Discovering an itchy skin welt often means you've been duped by one of Earth's sneakiest animals: the mosquito.

Scientists have puzzled over how the insects, often laden with two or three times their weight in blood, flee undetected. At least one species, *Anopheles coluzzii*, does so by relying more on lift from its wings than push from its legs to generate the force needed to take off from a host's skin, researchers report in the Oct. 15 *Journal of Experimental Biology*.

The insect's undetectable departure, which may help it avoid being smacked by an annoyed host, may be part of the reason *A. coluzzii* so effectively spreads malaria.

The new study provides "fascinating insight into life immediately after the bite, as the bloodsuckers make their escape," says Richard Bomphrey, a biomechanist at the Royal Veterinary College of the University of London.

To capture mosquito departures, Sofia Chang of the Animal Flight Laboratory at the University of California, Berkeley and colleagues set up a flight arena. Using high-speed video cameras, the team created computer reconstructions of mosquito takeoff mechanisms to compare with those of fruit flies.

Mosquitoes can lift off as fast as fruit flies but use only about a quarter of the leg force that fruit flies typically use to push off, Chang and colleagues found. And 61 percent of a mosquito's push-off force comes from its wings. As a result, a mosquito doesn't generate enough force on skin to be detected.

Unlike fruit flies' short legs, mosquitoes' long legs extend the insects' push-off time. That lets mosquitoes spread out already-minimal leg force over a longer time frame to reach similar takeoff speeds as fruit flies, the researchers found. This slow-and-steady mechanism is the same regardless of whether the bloodsuckers sense danger or are leaving of their own accord, and whether they are full of blood or have yet to get a meal.

Chang next wants to determine whether mosquitoes land as gently as they depart. ■

FLORIAN MUIJRES/WAGENINGEN UNIV.

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MATH & TECHNOLOGY

# Computer learns game with no help

## AlphaGo devises strategies unknown to human players

**BY MARIA TEMMING**

AlphaGo just leveled up.

The latest version of the computer program, dubbed AlphaGo Zero, is the first to master Go, a complex Chinese board game, without human guidance. Its predecessor, AlphaGo Lee, was the first computer program with artificial intelligence, or AI, to defeat a human world Go champion. AlphaGo Lee had to study millions of examples of human expert moves before playing practice games against itself. AlphaGo Zero trained solely through self play, starting with random moves. After a few days' practice, AlphaGo Zero trounced AlphaGo Lee 100 games to none, researchers report in the Oct. 19 *Nature*.

"The results are stunning," says computer scientist Jonathan Schaeffer of the University of Alberta in Edmonton, Canada. "We're talking about a revolutionary change."

AI programs that gain mastery of a task without human input may be able to solve problems where humans fall short, says Satinder Singh, a computer scientist at the University of Michigan in Ann Arbor. Such programs could find cures for diseases, design more energy-efficient technology or invent new materials.

AlphaGo Zero's creators at Google DeepMind let the program use a tactic during practice games that AlphaGo Lee didn't have access to. For each turn, AlphaGo Zero drew on its past experience to predict the most likely ways the rest of the game could play out, judge which player would win in each scenario and choose its move accordingly.

AlphaGo Lee used this kind of forethought in matches against other players, but not during practice games. AlphaGo Zero's ability to imagine and assess possible futures during training "allowed it to train faster, but also become a better player in the end," says Singh, who wrote a commentary in *Nature* about the study.

AlphaGo Zero played 4.9 million practice games over three days before defeating AlphaGo Lee. AlphaGo Lee's training period took months (*SN: 12/24/16, p. 28*). While practicing, AlphaGo Zero not only discovered many of the Go strategies that humans have come up with over thousands of years, but also devised new game plans previously unknown to humans.

Despite its Go-playing prowess, AlphaGo Zero is still "an idiot savant" that can't do anything except play Go, says Schaeffer. If AI programs are going to make superhuman contributions to engineering or medicine, they'll have to be more general-purpose problem solvers. ■

HUMANS & SOCIETY

## Europe's Stone Age fishers used beeswax to make spears

Late Stone Age people got a grip thanks to honeybees. Northern Central Europeans attached a barbed bone point to a handle of some kind with a beeswax adhesive around 13,000 years ago, scientists say. The result: a fishing spear.

Using beeswax glue to make tools was common in Africa as early as 40,000 years ago. But this spear, found in Germany, is the first evidence of using beeswax in cold parts of Europe at a time when glaciers were receding, say Michael Baales of LWL-Archäologie für Westfalen in Olpe, Germany, and colleagues.

Where the beeswax came from remains a question. Honeybees may have pushed north into Europe from warmer, Mediterranean locales several thousand years earlier than thought, the researchers propose in the October *Antiquity.* Or hunter-gatherers in northern Central Europe may have obtained beeswax through trade networks. *— Bruce Bower*


A roughly 13,000-year-old barbed bone point (shown from two sides) from Germany contains remnants of a beeswax glue near its base (left).

MATTER & ENERGY

## Proton size still perplexes physicists

Everyone agrees the proton is tiny: Its radius is less than a femtometer, or a trillionth of a millimeter. But scientists don't agree on exactly how small it is. A new measurement supports the case for a smaller proton, Lothar Maisenbacher of the Max Planck Institute of Quantum Optics in Garching, Germany, and colleagues report in the Oct. 6 *Science.*

The researchers peg the proton's radius at 0.83 femtometers; the textbook value is 0.88 femtometers. That discrepancy is stymieing scientists' attempts to test quantum electrodynamics, the theory of how electrically charged particles behave.

Physicists used to gauge the proton's girth either by firing electrons at protons and measuring how the electrons ricocheted, or by zapping hydrogen atoms with lasers to study the atoms' energy levels, which depend on the proton's size. Those measurements were in agreement.

But in 2010, scientists found a way to make measurements much more precise, by studying energy levels of muonic hydrogen — in which the electron is swapped for a heavier relative called a muon. Those measurements found the proton was 4 percent smaller than other estimates, or about 0.84 femtometers.

Some scientists thought the mismatch could be hinting at new physics, such as a new particle that interacts with muons but not electrons (*SN: 4/29/17, p. 22*).

Now, by making an improved measurement of energy levels in regular hydrogen, Maisenbacher and colleagues find a small proton, in close agreement with muonic hydrogen measurements. So a difference between electrons and muons is probably not the culprit. But the researchers still can't explain why other techniques get different results. *— Emily Conover*

ATOM & COSMOS

## Distance measured to spot on Milky Way's opposite side

For the first time, astronomers have directly measured the distance to a spot clear across the galaxy. The established but challenging technique promises a new way to map the structure of the Milky Way.

This method, called parallax, has measured distances to stars since the 1830s. But because of galactic dust in the way, it has been difficult to use parallax on stars on the opposite side of the galaxy. Other ways to measure distance are saddled with assumptions and uncertainties.

Researchers used the Very Long Baseline Array of radio telescopes in New Mexico to peer through the galactic dust and track a star-forming region in the outer Scutum-Centaurus spiral arm, which is on the opposite side of the Milky Way from the sun. Alberto Sanna of the Max Planck Institute for Radio Astronomy in Bonn, Germany, and colleagues report in the Oct. 13 *Science* that the region is over 66,500 light-years away.

The team observed the distant spot for a year, drew an imaginary triangle between it and two points in Earth's orbit, and then used trigonometry to measure the distance. Applying the same technique to other regions of the Milky Way will help astronomers figure out what our galaxy looks like from the outside and compare it with other spiral galaxies. *— Lisa Grossman*

EARTH & ENVIRONMENT

## Volcanoes may have doomed ancient Egypt's last dynasty

A series of volcanic eruptions may have helped bring about the downfall of the last Egyptian dynasty 2,000 years ago.

By suppressing the monsoons that triggered the flooding of the Nile River, which supported agriculture, eruptions probably helped usher in an era of periodic revolts, researchers report October 17 in *Nature Communications.* That upheaval ultimately doomed the dynasty that ruled Egypt's Ptolemaic Kingdom for nearly 300 years until the death of Cleopatra.

To piece together this puzzle, Yale historian Joseph Manning and colleagues compared records of Nile River heights dating back to A.D. 622 with eruptions recorded in ice cores from Greenland and Antarctica that go back 2,500 years. Layers of sulfate particles erupted by volcanoes, preserved in the ice, were linked to years of less extensive flooding.

To see how eruptions would have affected precipitation in Ptolemaic Egypt, the researchers simulated how climate changed after five large 20th century eruptions. Each eruption reduced monsoon rains across parts of Africa that drain into the Nile, by shifting and weakening the Intertropical Convergence Zone, a belt of low pressure near the equator that drives nearby precipitation patterns.

Finally, Manning and colleagues found that the onset of many revolts recorded in Ptolemaic Egyptian texts coincided with volcanism recorded in ice cores. Political instability, famine and drought may have come to a head around 44 B.C., when a big volcano, possibly Italy's Mount Etna, erupted, and the Ptolemaic dynasty came to a close in 30 B.C. with Cleopatra's suicide. *— Carolyn Gramling*

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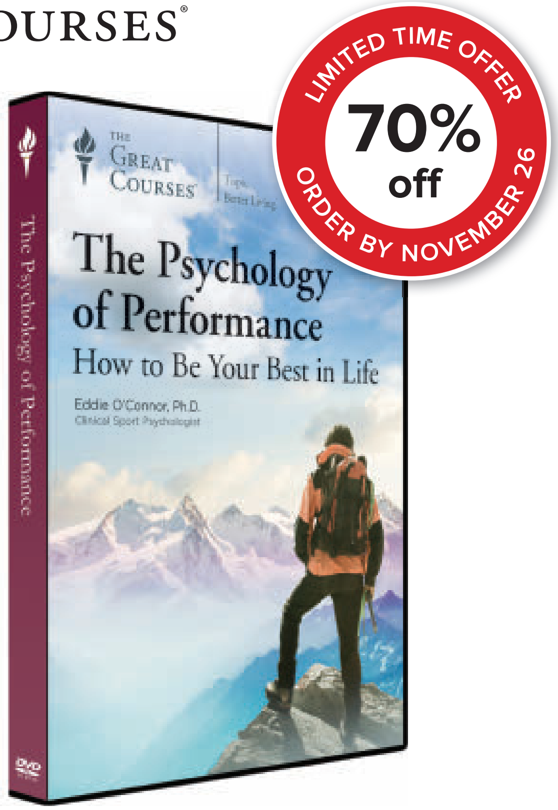


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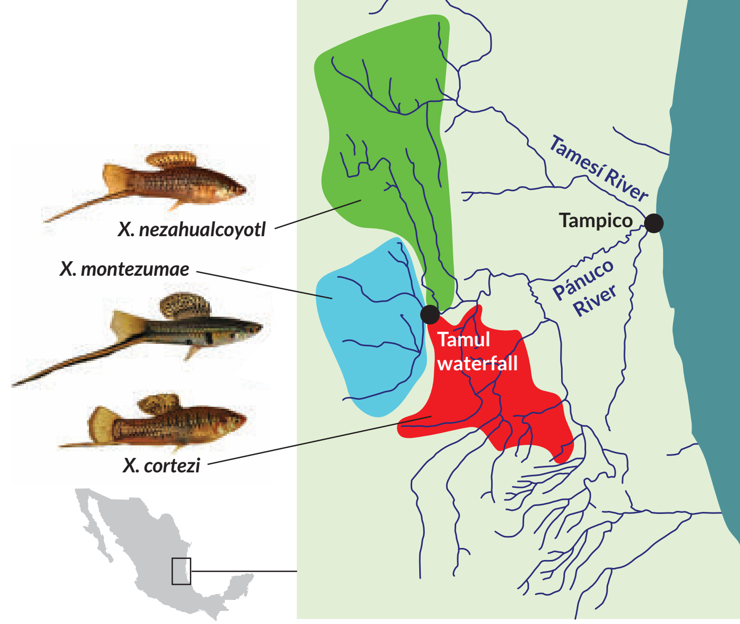
# HYBRIDS TELL TALES

# When species manage to mix, they offer clues to reproductive barriers

## By Tina Hesman Saey




**Mingling fish** The swordtail fish *Xiphophorus nezahualcoyotl* inhabits certain rivers in Mexico (green shows range). The species is a hybrid of *X. montezumae* (blue) and *X. cortezi* (red), found in different rivers. The interbreeding between those species probably took place more than 2,500 generations ago, though swordtails in other rivers have hybridized more recently.

It's a tale as old as wine. Two organisms meet over a barrel of alcohol and decide to mate.

Geneticist Maitreya Dunham didn't see it happen. But she has molecular evidence that two yeast species produced a hybrid in an old warehouse turned microbrewery. The two species had grown apart, evolutionarily speaking, about 10 million to 20 million years ago, Dunham, of the University of Washington in Seattle, and colleagues calculate. Yet the distant relatives interbred, producing the hybrid that ended up in a barrel of wild beer.

But wait a minute, some people may adamantly argue: Separate species can't mate and reproduce. Much of the time, those hybrid deniers are right. But hybrids do happen, far more often than scientists used to think, says Molly Schumer, an evolutionary geneticist at Harvard University. Plants are famous cross-species breeders. Yeasts do it all the time, especially in the nutrient-rich microbe "meet market" that is a brewery, Dunham says. "It's like a yeast hookup zone."

Researchers have discovered fish, birds, mice, fruit flies and other animals in the wild carrying DNA from parents of different species. Perhaps the biggest shocker of all was the 2010 discovery that humans had interbred with Neandertals after leaving Africa. Humans still carry genetic souvenirs of the encounters (*SN: 6/5/10, p. 5*). These discoveries would seem to contradict the biological species concept, which holds that separate species can't mate and produce fertile offspring (see Page 22).

But the blurred lines between species don't bother many researchers, says evolutionary biologist Glenn-Peter Sætre of the University of Oslo. He and others are learning from that blurry zone, the place where hybrids thrive or sometimes fail. Finding out why some hybrids make it and others don't may yield molecular details about how reproductive barriers between species are built, says evolutionary population geneticist Graham Coop of the University of California, Davis. Studying fully reproductively separated species is no good; their barriers are well established, and it's difficult to know which bricks were laid first. With hybrids, researchers can watch the barriers being erected, Coop and others say. Those studies give researchers insight into the process of speciation, the separation of a population into different species.

Scientists have begun to build a list of "speciation genes" — different in different species — that help establish and maintain that parting of the ways. Despite the name, the job of those genes isn't to draw lines in the sand between species. Those lines are a side effect of the genetic tweaks species gather by chance or while adapting to new environments.

### Dead-end hybrids

When Schumer began working with species of swordtail fish in Mexican rivers about six years ago, scientists still thought hybrids were rare among animals. But the fishes' DNA told another tale. Their genetic blueprints, or genomes, were patchworks of different species' DNA, indicating interbreeding with at least one other relative in the recent past. And by recent, Schumer means that hybridization became the rage among two species of Mexican swordtails just within the last 20 to 30 years (*SN Online: 5/21/14*). "We weren't clear at the time if [hybridization] was something weird about swordtails," she says, "but it's becoming clear that many species groups are that way."

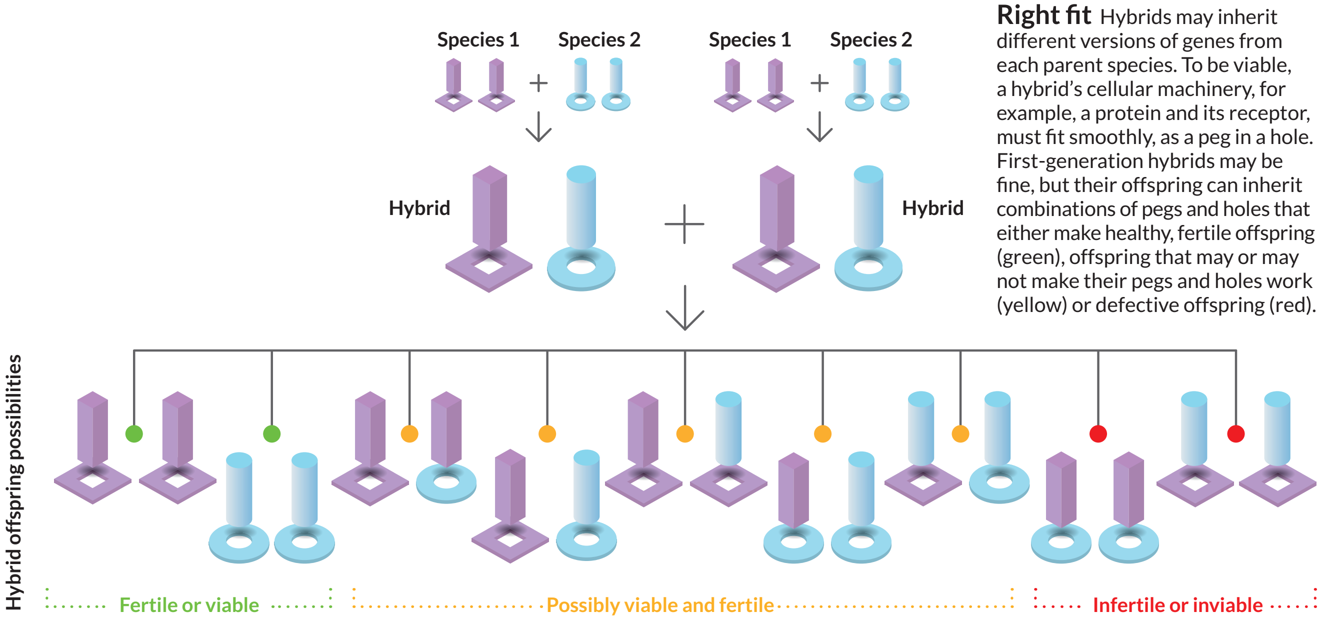
Sometimes, hybridization brings benefits. For example, the famous Galápagos Islands finches named for Charles Darwin picked up survival advantages by interbreeding with other finch species (*SN: 3/7/15, p. 7*). But more often, hybrids don't happen.

Geographical barriers (mountains high enough, rivers wide enough) can prevent interspecies contact, as can out-of-sync mating cycles. Even when mating actually occurs, barriers still exist, says Michael Nachman, a population geneticist at the University of California, Berkeley. Fertility in hybrids is often subpar. Sperm from one species may not be able to fuse with eggs from another, and other molecular incompatibilities may cause embryos to fail. Sometimes being a hybrid is a death sentence. Those problems have genetic and physiological roots that scientists are only beginning to understand.

A hybrid combines the genomes of both parents, a process similar to combining parts from two machines built under

Italian sparrows, formed from interbreeding between house and Spanish sparrows, are a hybrid success story. Scientists are studying genetic changes that helped the Italian sparrows adapt to their environment and remain independent from their parent species.

OPPSOTE PAGE: NICOLLE RAGER FULLER; M. SCHUMER *ET AL*/*MOL. ECOL.* 2016, MAP ADAPTED BY C. CHANG




**Right fit** Hybrids may inherit different versions of genes from each parent species. To be viable, a hybrid's cellular machinery, for example, a protein and its receptor, must fit smoothly, as a peg in a hole. First-generation hybrids may be fine, but their offspring can inherit combinations of pegs and holes that either make healthy, fertile offspring (green), offspring that may or may not make their pegs and holes work (yellow) or defective offspring (red).

slightly different measuring systems. "You can take two fully functional complex machines and put them together and the whole thing falls apart," says evolutionary geneticist Nitin Phadnis. Scientists can learn how species form by studying the wreckage of such hybrid machinery. In 2009, Phadnis, now at the University of Utah in Salt Lake City, and H. Allen Orr of the University of Rochester in New York discovered, in fruit flies, one of the first known speciation genes.

Things don't necessarily fall apart right away, says Polly Campbell, an evolutionary geneticist at Oklahoma State University in Stillwater. As two species spend time apart adapting to separate environments, many changes accumulate in the species' DNA. Such changes, or mutations, may alter the function or the structure of proteins produced by the genes. In a first-generation hybrid, those changes may not be visible. Parent Species A's genes produce cogs that fit its cellular machinery and Parent Species B's genes do the same. The hybrid inherits components to assemble fully functional versions of both parents' machinery. But when hybrids go on to breed with each other, their offspring inherit different combinations of the original parent species' genes. Sometimes that works out fine: A small proportion of the next generation may inherit all A machinery or all B machinery. Another proportion of offspring may get a mix of A and B cogs, but might be able to cobble together a biological machine that works well enough. A third segment of the offspring won't be so lucky: They will be stuck trying to fit Species A's cogs in an otherwise Species B machine (or vice versa), like a square peg in a round hole. Over time, enough offspring can inherit unworkable combinations of pegs and holes that the hybrids die out.

Britannia Wanstrath has seen hybrid wreckage up-close. She is a technician who oversees mouse breeding and welfare at the University of North Carolina at Chapel Hill.

While trying to create better mouse strains for studying human diseases, she and other researchers may have inadvertently stumbled upon genes that render hybrids as dead ends. A massive effort known as the Collaborative Cross yielded 738 hybrid mouse lines by breeding an original eight strains of mice from three different subspecies, *Mus musculus domesticus*, *M. musculus musculus* and *M. musculus castaneus* (*SN Online: 2/17/12*). Those subspecies (or maybe species — the dividing line is fuzzy) are genetically similar. Because of small differences among the subspecies, researchers expected that a few of the new strains wouldn't make it, says geneticist Fernando Pardo-Manuel de Villena, also at UNC Chapel Hill. "We expected some extinction, but very, very minor."

Instead, 95 percent of the 738 hybrid Collaborative Cross lines have gone extinct, Pardo-Manuel de Villena and colleagues reported in the June issue of *Genetics*.

One of the mouse lines that expired, dubbed 5262, had particularly wild mice that were "difficult to handle and very vocal when agitated," Wanstrath says. As researchers began breeding relatives in the line to each other so they would all be genetically identical, 5262's breeding slowed. The inbred litters died soon after birth. The researchers tried everything they could think of to keep the line going, Wanstrath says. "Nothing worked." Eventually, the last litter was born: one male and one female pup survived. The researchers were excited that they might be able to keep the line going. But the female died 12 days after birth and her brother was left alone. End of the line.

The researchers examined male mice from 347 of the extinct lines to find out what was going on. About 47 percent of the male mice in the extinct lines were infertile because of gene defects that prevented them from making good sperm. Some made no sperm. Some produced sperm with broken tails,

C. CHANG

unable to swim. Of the 183 male lines that were fertile, 99 could produce offspring only with distantly related females.

The scale of that extinction was unexpected, Campbell says, but male fertility problems aren't a big surprise. Sperm production is a fragile process, she says. Still, those problems didn't show up right away. It took generations of inbreeding to doom some hybrids. In the case of mice from the extinct lines, each round of inbreeding distributed the pegs and holes until the pieces no longer fit. In other lines, the sorting made workable combinations.

## The barrier genes

Researchers traced some of the hybrid mice's fertility glitches to problems on the X chromosome. But this is bigger than one chromosome. "Many, many genes," perhaps hundreds or thousands, are responsible for the incompatibility, Pardo-Manuel de Villena says. "They are located almost everywhere in the genome." Because so many gene combinations led to extinction, it's nearly impossible to say which are most important.

UC Berkeley's Nachman agrees that it's not easy to figure out which of the thousands of genes in a hybrid's genome is a speciation gene. He should know. "I've been searching for the last 10 years, and I've yet to find one," he says.

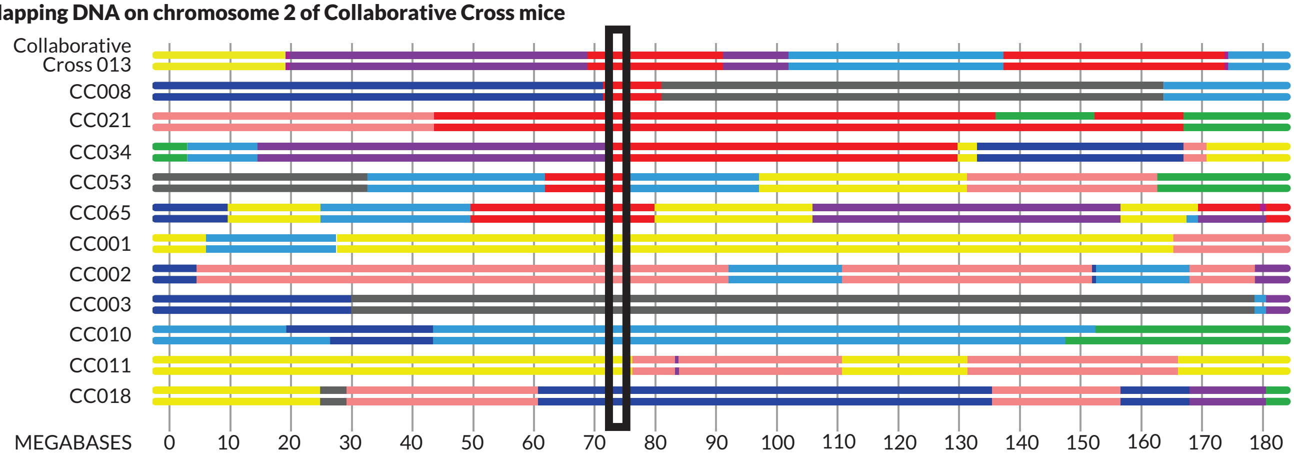
In fact, in mammals, only one speciation gene has been identified so far. Geneticist Jiří Forejt of the Czech Academy of Sciences' Institute of Molecular Genetics in Prague wasn't looking for it when he caught wild mice and bred them with lab mice to study diversity of immune system genes. Hybrid males from those liaisons were sterile, he and colleagues discovered. "We had no idea we were working with two subspecies, *musculus* and *domesticus*," he says. In 1974, Forejt narrowed the problem to a gene on one chromosome, then finally revealed the gene's identity in 2009: *PRDM9*, which produces a protein that determines where on chromosomes genetic information gets swapped.

When making sperm and eggs, organisms halve the number of chromosomes in those cells in a process called meiosis. That halving is necessary so that when an egg and sperm meet in fertilization, the embryo will have the correct number of chromosomes: half from the mother and half from the father. Cells going through meiosis must pass certain checkpoints. One of the biggest involves pairing the chromosomes to exchange bits with each other. That recombination is an important force in the evolution of sexually reproducing organisms because it allows for new combinations of genes.

In many mammals, including humans and mice, the PRDM9 protein marks where recombination will take place — the molecular equivalent of the orange flags that utility crews use to mark digging locations. PRDM9 grabs DNA using structures called zinc fingers. During evolution, those fingers develop a touch for different DNA sequences in different species. The sequence grabbed by *M. musculus musculus*' PRDM9 zinc fingers is slightly different from the ones preferred by *M. musculus domesticus*' zinc fingers. And so, the two subspecies

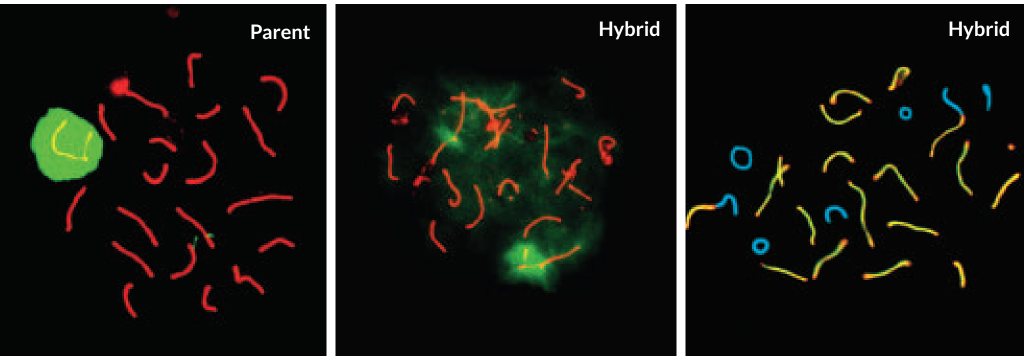
A male mouse (brown) from a nearly extinct line of hybrid mice is introduced to a female from a fertile strain to see if they would mate and make pups. But as the mice sniff each other in greeting, the female spurns the male's advances with a paw to the face.

**Mapping DNA on chromosome 2 of Collaborative Cross mice**




**Up to speed** Each color above represents DNA on chromosome 2 from an originating parent strain in the Collaborative Cross project, a large panel of inbred mice. Hybrid offspring with red in the black vertical box had DNA from one strain, called PWK/PhJ, and their sperm had faster back and forth motion than mice with DNA from other strains. Sperm motility may have been a problem for some of the strains that went extinct.

FROM TOP: B. WANSTRATH; J.R. SHORTER *ET AL*/*GENETICS* 2017




**Right connections** When male mice from a strain of *Mus musculus domesticus* mate with females from a different subspecies, their male offspring are often sterile. In each parent subspecies (left), chromosomes pair up (red) to exchange DNA, and a sex body (green) forms around the X and Y chromosomes. In hybrids, the sex body is disrupted (middle panel, green) and some chromosomes don't pair up correctly (right panel, blue). Chromosomes sharing DNA normally are shown in yellow.

carry out their DNA swaps at different places along the chromosomes. Mismatched recombination sites can hold up egg and sperm production, leaving hybrids infertile.

Details about how important it is to have the right zinc fingers came in a report last year in *Nature*. By re-engineering PRDM9's zinc fingers, researchers moved recombination hot spots and restored fertility in male hybrid mice.

But *PRDM9* can't take all the blame for hybrid sterility between those mouse subspecies. "In many cases it's combinations of many genes that result in this failure," Forejt says. He and colleagues reported last year in *PLOS Genetics* that they had tracked another speciation gene that interacts with *PRDM9* to a stretch of 4 million DNA bases on the X chromosome. There are at least six other genes in that part of the chromosome, and Forejt doesn't yet know which one is a speciation gene.

Sometimes, *PRDM9* plays no role in incompatibility. Many animals, including dogs, birds, crocodiles and amphibians, don't have a working version of the gene, or don't use it.

### Success for sparrows

Some hybrids, including some of Schumer's fish and Darwin's finches, have overcome whatever barriers might have been in the way of hybridization. These organisms have sorted out their parents' differences and formed viable species of their own. Oslo's Sætre and colleagues are studying one such species, the Italian sparrow, a blend of Spanish sparrows and house sparrows.

The bird's origin story starts in the Middle East, where one of its parents, the house sparrow (*Passer domesticus*), is native. In the last 10,000 years, house sparrows accompanied early farmers on migrations into Europe. There, the house sparrows encountered Spanish sparrows (*Passer hispaniolensis*), found in Europe and northern Africa. Mating between the species produced the Italian sparrow (*Passer italiae*), which lives on the Italian mainland and a few Mediterranean islands.

Italian sparrows aren't simple 1-to-1 mixtures of their parent species' genes, Sætre and colleagues discovered. On average, 61.9 percent of the Italian sparrow's DNA comes from house sparrows and 38.1 percent from Spanish sparrows, the researchers reported June 14 in *Science Advances*.

"The genomes of these species have combined, but they've also been sorted," Sætre says, yielding those unequal proportions. In some parts of the Italian sparrow's genome, house sparrow genes have been purged, leaving only Spanish sparrow DNA. In other sections, the Spanish sparrow contribution got the heave-ho. Such genetic housecleaning was probably necessary to get a mix of genes that could work together.

Today, Italian sparrows are largely cut off from their parents in the reproductive arena, Sætre says. In southern Italy where Italian and Spanish sparrows cross paths, Sætre and colleagues have tested more than 1,000 sparrows across several studies. Not a single one was a Spanish-Italian first-generation hybrid, indicating that impediments to breeding between the two species are high. In the Alps, Italian and house sparrows can sometimes breed, though genetic evidence suggests they rarely do. That reproductive isolation from its parents gives the Italian sparrow independent species status.

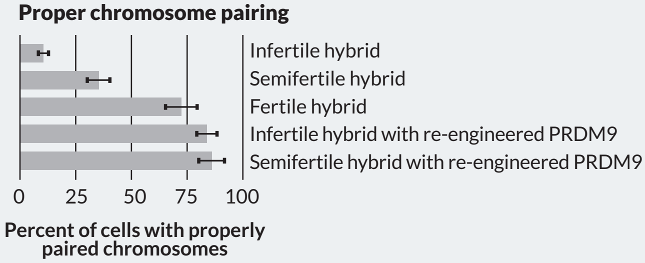
In the Italian sparrow, some genes have been tweaked from versions found in the parent species. These altered stretches of DNA are speciation gene suspects, but how such gene tweaks block reproduction isn't known. "We're not in a place where we can say what goes wrong biochemically," Sætre says.

### Checkpoint discoveries

Few researchers can point to a particular molecular wrench in the works that makes hybrids inviable, Phadnis says. "This

**Course correction** Good chromosome pairing happens less often in infertile and semifertile hybrids than in fertile hybrids. Re-engineering the version of PRDM9 in infertile and semifertile hybrid mice corrected chromosome pairing and restored fertility (bottom two rows).

**Proper chromosome pairing**




BOTH: B. DAVIES *ET AL*/*NATURE* 2016

is still cutting-edge science and an unsolved problem."

In the few cases in which researchers have a handle on which genes are making hybrids sterile, there's no guarantee the same genes or processes are involved in every failed species mash-up, he says. But he and colleagues are exploring a notion of what might be going wrong for some hybrids.

Phadnis and colleagues have proposed a solution for an almost 100-year-old question about why crossing *Drosophila melanogaster* fruit flies with flies from its sister species *Drosophila simulans* results in dead male offspring. Researchers had already discovered that *D. melanogaster* has a gene called *Hmr* that's involved in divvying up chromosomes. *Hmr* doesn't play well with *Lhr*, a *D. simulans* gene that also helps make sure chromosomes are doled out properly. Scientists knew a third gene was involved in species' incompatibility, but researchers had technical difficulties identifying it. Phadnis and colleagues reported in *Science* in 2015 that the gene called *Su(Kpn)* encodes a checkpoint protein, one that determines whether a cell has completed certain tasks and can go on to divide.

Some of the molecular details are unknown, but Phadnis and colleagues propose that discrepancies between *Hmr* and *Lhr* may mess with the way cells divide their chromosomes. Because of the messed-up chromosomes, *Su(Kpn)* halts further cell division, arresting development and causing death of male offspring only, the researchers propose.

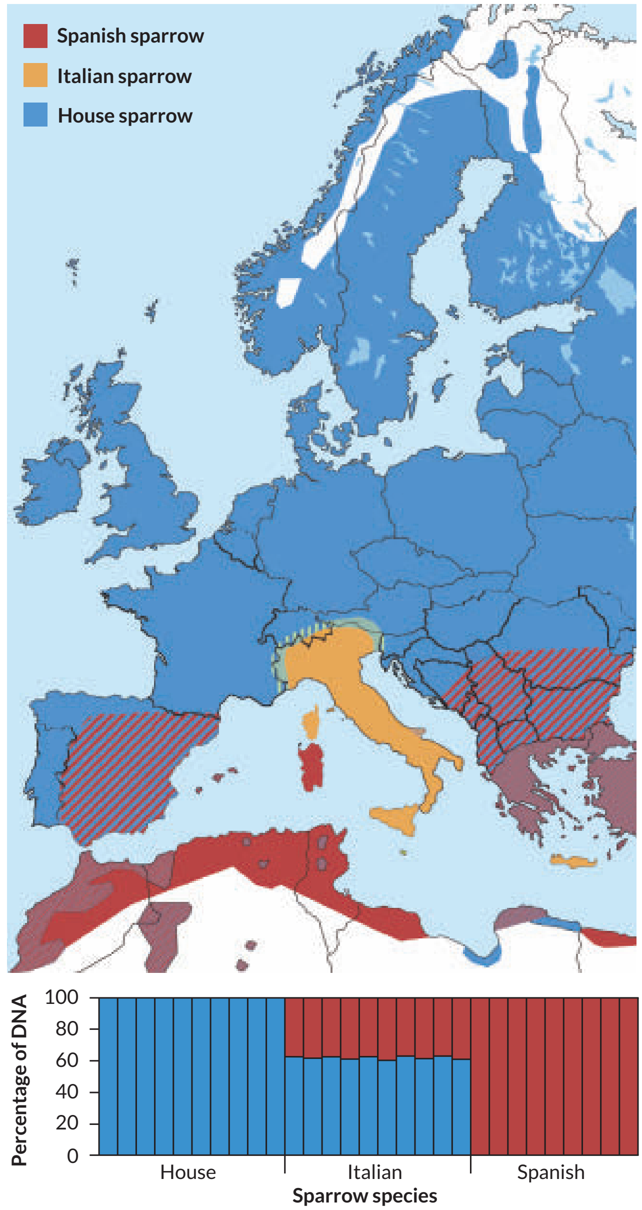
Arrested cell division may also be a problem for lab-made hybrids of two subspecies of *Drosophila pseudoobscura* on their way to becoming separate species. About 150,000 to 230,000 years ago, two subspecies — USA and Bogota — started to drift apart. Now, mating Bogota females and USA males produces infertile male hybrid offspring. The hybrid males can become weakly fertile in old age, but they produce mostly daughters. In 2009, Phadnis and Orr described in *Science* what was happening. The problem is selfishness. Specifically, a gene called *Overdrive* acts as a "selfish element" and skews sperm production so that hybrid males mainly make sperm carrying X chromosomes. That leaves only female offspring.

But *Overdrive* doesn't work alone. At least six other genes are involved in the male sterility, Phadnis reported in 2011 in *Genetics*. As the USA and Bogota subspecies spend more and more time apart, they may layer on additional barriers. In unpublished work, Phadnis has discovered that *Overdrive* may also be putting the brakes on development, just as *Su(Kpn)* does. Its stopping power gets weaker with age, allowing some sperm production. Phadnis doesn't know all the details yet, but then neither does anyone else.

"Despite a lot of effort, there really isn't a single system in which you can tell the complete details of any hybrid incompatibility," Phadnis says.

Even the yeasts that hybridize so readily in Maitreya Dunham's beer barrel and that she intentionally breeds in her lab don't have the whole hybridization thing worked out. Hybrid yeast often have fertility problems when reproducing sexually. Luckily for them, yeast can reproduce asexually, essentially making clones of themselves forever, Dunham says. "It doesn't matter how messed up your genome is if you can make clones of yourself." ■

**Unequal partnership** When house sparrows migrated from the Middle East to Europe (geographic range, blue), they mated with Spanish sparrows (red) to form Italian sparrows (yellow). DNA analysis (graph) shows that Italian sparrows have purged genes from both parents. Their genomes average 61.9 percent house sparrow and 38.1 percent Spanish sparrow.




T.O. ELGVIN ET AL/SCIENCE ADVANCES 2017

## Explore more


- Tore O. Elgvin *et al.* "The genomic mosaicism of hybrid speciation." *Science Advances.* June 14, 2017.
- Nitin Phadnis. "Genetic architecture of male sterility and segregation distortion in *Drosophila pseudoobscura* Bogota–USA hybrids." *Genetics.* November 2011.

# The fuzzy art of defining species

## A vital concept sparks many arguments **By Susan Milius**

The funniest thing I've ever said to any botanist was, "What *is* a species?" Well, it certainly got the most spontaneous laugh. I don't think Barbara Ertter, who doesn't remember the long-ago moment, was being mean. Her laugh was more of a "where do I even start" response to an almost impossible question.

At first glance, "species" is a basic vocabulary word schoolchildren can ace on a test by reciting something close to: a group of living things that create fertile offspring when mating with each other but not when mating with outsiders. Ask scientists who devote careers to designating those species, however, and there's no typical answer. Scientists do not agree.

"You may be stirring up a hornet's nest," warns evolutionary zoologist Frank E. Zachos of Austria's Natural History Museum Vienna when I ask my "what is a species" question. "People sometimes react very emotionally when it comes to species concepts." He should know, having cataloged 32 of them in his 2016 overview, *Species Concepts in Biology*.

The widespread schoolroom definition above, known as the biological species concept, is No. 2 in his catalog, which he tactfully arranges in alphabetical order. This single concept has been so pervasive that whenever *Science News* publishes something about species interbreeding (see Page 16), readers want to know if we have lost our grip on logic. Separate species, by definition, can do no such thing.

As concerned readers question our reports of hybrid species, a vast debate among specialists over how to define and identify species rolls on. The biological species concept has drawbacks, to put it gently, for coping with much of the variety and oddness of life. Alternative concepts have pros and cons, too. As specialists argue over the fine details of species concepts, I'm struck by how often the word "fuzzy" comes up.

Also striking is how at least some of the people who actually appraise species for a living have made peace with the perpetual tumult over defining just what it is they get up in the morning to study. The ambiguities seemed less jarring to me after a September conversation with the Smithsonian's Kevin de Queiroz, deep in the maze of doors and corridors behind the scenes at the National Museum of Natural History in Washington, D.C. As a systematic biologist, he

This swarm of diversely patterned *Heliconius* butterflies is actually just two species known for mimicry. How to define a species turns out to have more pitfalls than these butterflies have spots.

NICOLLE RAGER FULLER

studies the evolutionary histories of reptiles, and designates species, which explains a door we passed marked "Alcohol Room." Fire regulations require special handling for jars of animal specimens preserved in alcohol. In the cacophony of species concepts, de Queiroz sees some commonality.

Ertter, affiliated with the University of California, Berkeley and the College of Idaho in Caldwell, embraces the ambiguity. "Why do we expect that nature is nice and neat and clean? Because it's more convenient for us," she says. "It's up to us to figure it out, not to demand that it's one way or another."

## Problems with the old standard

The biological species concept has an intuitive appeal. Elephants don't mate with oak trees to produce really big acorns. Horses can mate with donkeys, but the resulting mules are infertile. The most famous form of this species definition may be from evolutionary biologist Ernst Mayr, who wrote in 1942: "Species are groups of actually or potentially interbreeding natural populations, which are reproductively isolated from other such groups." Famous, yes, but limited.

Modern genetics has revealed that much of the diversity of life on Earth is found in single-celled organisms that reproduce asexually by splitting in two — thus flummoxing the definition. Of course the single-celled hordes still form … somethings. There isn't just one vast smear of microbial life where all shapes, sizes, body features and chemistry can be found in any old mix. There are clusters with shared traits, some of which cause human and agricultural diseases and some of which photosynthesize in the ocean, producing as much as 70 percent of the oxygen that we and other living things breathe. Humans need to understand the history of microbes and have names to talk about these influential organisms.

Rather than deciding that these microbes are just not species, which is one popular view, microbiome researcher Seth Bordenstein suggests "just twisting the biological species concept ever so slightly." Genes don't shuffle around via sex, but there's still kidnapping of genes from other asexuals. This process might count as something like interbreeding, says Bordenstein, of Vanderbilt University in Nashville. With that interpretation, the biological species concept "could apply to microbes." Sort of.

But one-celled microbes aren't the only asexuals. Even vertebrates have their no-sex scandals. New Mexico whiptail lizards are a species: *Aspidoscelis neomexicanus*. Yet females lay eggs with no male fertilization; males don't exist.

And plant reproduction, oy. The blends of sex and no-sex don't fit into a tidy biological species concept. Consider a new variety of a western North American species that Ertter and botanist Alexa DiNicola of the University of Wisconsin–Madison named this year. *Potentilla versicolor var. darrachii* belongs to a genus that's closely related to strawberries. Plants in the genus open little five-petaled flowers and readily form classic seeds that mix genes from pollen and ovule. On occasion, though, the genes in the seed's embryo are only mom's. "They basically use seeds as a form of cloning," Ertter says. The male pollen in these cases merely jump-starts formation of the seed's food supply.

That's just one reason *Potentilla* is "one of the messiest genera you can imagine," Ertter says. She and DiNicola hauled collectors' gear on a backpacking trip in Oregon to sample some of the plants. The team found signs that one species was hybridizing readily with another; the species were so different that even a nonbotanist could tell them apart (leaves shaped like a feather versus an open fan). Sharing genes across species is evidently common in this genus and not at all rare among plants.

Such shenanigans have led Ertter to what she calls the "fuzzy species concept." After looking at all the kinds of evidence she might muster for a plant, from its genes and distribution to the details of petals, leaf hairs and other parts, she sides with the preponderance of data to designate a species.

## Concept zoo

There can be a lot of messiness in picking out the limits of species, but that's OK with philosopher Matt Haber of the University of Utah in Salt Lake City. He organized three conferences this year on the complications of determining what's a species when fire hoses of genetic information spew signs of unexpected gene mixing and tell different stories depending on the genes tracked.

"Just because boundaries are fuzzy," Haber says, "doesn't mean they aren't actually boundaries." We may not be used to thinking about species distinctions this way, but other familiar distinctions have similar "gradient boundaries," as he calls them. "Cold and hot weather," he says. We recognize winter weather as different from summer even though fall and spring have neither a sharp switch point nor a smooth slide. Species, too, could have zones of erratic mixing but still overall be defined as species.

There are a whole lot of species concepts, says Richard Richards, a philosopher of biology at the University of Alabama in Tuscaloosa. "We use different rules for different

**A rough idea** Extremely squeezed-down summaries of just a few of the dozens of species concepts give a rough sense of the differing approaches researchers use to define a species. The full statements for each concept are far more intricate.

| Species concept | A species is … |
|---|---|
| Morphological | the smallest group with a persistent difference in form |
| Ecological | a lineage with its own distinct ecological niche |
| Genetic | a group of natural interbreeders genetically separated from other groups |
| Bioeconomic | a unit in the natural economy that competes reproductively with other units |

kinds of organisms," he says. "For vertebrates, the interbreeding rule is useful. Not so for the many kinds of nonsexually reproducing organisms out there."

What's called the agamospecies concept applies to asexual organisms and cobbles together genetic or other observable similarities. The ecological species concept emphasizes adaptations to particular environmental zones. The nothospecies concept applies to plants arising when parent species hybridize. And so on. That's not even counting "the cynical species concept," which Zachos has heard defining a species as "whatever a taxonomist says it is."

## Land and money

Species definitions can have ramifications, financial and otherwise, for the wider world. Choosing one species concept over another can change how a creature gets classified, which could determine whether conservation laws protect it. The coastal California gnatcatcher's status as a distinct subspecies makes it eligible for federal protection to keep the bird's shrubland as habitat rather than a real estate development. Critics have argued, however, that the bird isn't distinct enough from its relatives to merit special protection.

Mammal specialists are switching over to what's called a phylogenetic concept, Zachos says. The phylogenetic concept allows populations to upgrade to full species status if they share an ancestor and have some unique trait, such as a particular gene. Among the complex consequences of following this concept is possible "taxonomic inflation," he warns. A 2011 rethink of the ungulate group of sheep, goats, antelope and more ballooned the species count from 143 to 279, for instance. In biology as in economics, "inflation causes devaluation," Zachos says. "People get bored. If one of the tiger species goes extinct, they say, 'So what? There are five more.' "

As individual taxonomists choose their pet concepts, " 'species' are often created or dismissed arbitrarily," argued two researchers from Australia in the June 1 *Nature*. The duo warned of potential "anarchy" and went as far as calling for an international organization to reduce the chaos.

"A long list of silly examples of complications caused by poor taxonomic governance" pushed conservation biologist Stephen Garnett of Charles Darwin University in Darwin to cowrite the piece. Standardizing species concepts across broad groups, mammals and reptiles, for instance, would reduce the chaos, says coauthor Leslie Christidis, a taxonomist at Southern Cross University in Coffs Harbour. The notion of standard-setting in determining species has stirred a bit of agreement and a lot of dissent. "We united the taxonomic community — unfortunately against us," he says.

The furor illustrates the diversity of ways that people are sorting out what a species is among life's various organisms. Historian and philosopher of biology John S. Wilkins of the University of Melbourne in Australia was almost kidding when he wrote that there are "n+1 definitions of 'species' in a room of n biologists."

All-female New Mexico whiptail lizards, hybridizing *Potentilla* flowers and group-reproducing slime molds (wolf's milk, shown) breed in ways that poke holes in the familiar biological species concept.

## The commons

Thinking about the seemingly intractable ambiguities of the species concepts got a lot easier for me after my visit with de Queiroz. His office was the opposite of the Hollywood biologist's jumble of dessicated specimens, dangling skeletons and tottering towers of books. The long room was mostly filled with rows of librarian-tidy metal bookcases hiding a desk cave at the far end. When I asked him what a species is, he didn't laugh. He explained that there's more agreement than the swarm of species concepts might suggest.

The concepts have in common their references to organisms in a population lineage, or line of descent. As evolutionary time passes, a lineage moves away and its various connected populations grow separate from others of the same ancestry. The concepts share the basic idea that a species is a "separately evolving metapopulation lineage," he says.

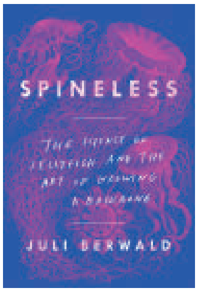
To identify those lineages in practice, however, requires finding evidence of interbreeding or patterns of shared traits. Adding such criteria to the concepts is what creates the crazy diversity. Defining the term species is "not the problem," he says. "The problem is in *identifying* a species."

He calls up a map on his computer from a recent paper a former lab member published on fringe-toed lizards. Colored blobs float over dark lines of a map of the western United States. Three blobs are clearly designated species based on multiple lines of evidence. Three lizard patches, however, are perplexing. Various ways of testing these lizard populations lead to contradictory results.

No matter how badly we want the process of applying a species definition to be clear-cut for all creatures in all cases, "it just isn't," de Queiroz says. And that's exactly what evolutionary biology predicts. Evolution is an ongoing process, with lineages splitting or rejoining at their own pace. Exploring a living, ever-evolving world of life means finding and accepting fuzziness. ■

## Explore more

■ Frank E. Zachos. *Species Concepts in Biology*. Springer, 2016.




**Spineless**
*Juli Berwald*
RIVERHEAD BOOKS, $27

BOOKSHELF

## The real story on the jellyfish take-over

Jellyfish have gotten a bad rap. In recent years, concerns about rising jellyfish populations in some parts of the world have mushroomed into headlines like "Meet your new jellyfish overlords." These floating menaces are taking over the world's oceans thanks to climate change and ocean acidification, the thinking goes, and soon waters will be filled with little more than the animals' pulsating goo.

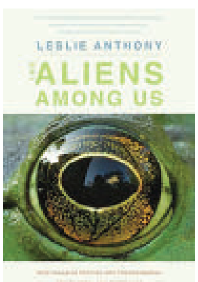
It's a vivid and frightening image, but researchers aren't at all certain that it's true. In her new book, *Spineless*, former marine scientist Juli Berwald sets out to find the truth about the jellyfish take-over. In the process, she shares much more about these fascinating creatures than merely their numbers.

Among a few of the amazing jellyfish facts and tales throughout the book: Jellyfish have astoundingly complex vision for animals without a brain. They are also the most efficient swimmers ever studied, among the most ancient animals surviving on Earth today and some of the most toxic sea creatures (*SN: 9/6/14, p. 16*).

Rather than merely reciting these facts, Berwald takes readers on a personal journey, tracing how life pulled her away from science after she earned her Ph.D. — and how jellies brought her back. Through the tale of her experiments with a home jellyfish aquarium, she explains jelly biology, from the amazing shape-shifting properties of the mesoglea that forms a jellyfish's bulk to why so many species are transparent. As she juggles family life with interviews with the world's leading jellyfish researchers, Berwald also documents her travels to places around the globe where jellyfish and humans intersect, such as Israel's coral reefs and Japan's fisheries.

The answer to the question of whether jellyfish populations are on the rise ultimately lies at this intersection, Berwald finds. Marine scientists are split on whether populations are increasing globally. It depends on which data you include, and it's possible that jellyfish numbers fluctuate naturally on a 20-year cycle. What is clear is that in coastal areas around the world, people have unwittingly created spawning grounds for huge numbers of jellyfish simply by building docks and other structures that quickly multiplying jellyfish polyps can attach to.

In the end, Berwald says, jellyfish became a "vehicle for me to explore the threats to the ocean's future. They're a way to start a conversation about things that can seem boring and abstract — acidification, warming, overfishing and coastal development — but that are changing our oceans in fundamental ways." And that's more interesting than an ocean full of goo. *— Erika Engelhaupt*




**The Aliens Among Us**
*Leslie Anthony*
YALE UNIV. PRESS, $30

BOOKSHELF

## Invasive species are a growing global threat

Remote Bouvet Island, a tiny, glacier-smothered landmass in the South Atlantic rimmed by 500-meter-tall cliffs, has a notable distinction: It's the only known spot on Earth, scientists say, that has zero invasive species. Every other place, and every person, on the planet is at least indirectly affected by one or more species that has been transported — either intentionally or inadvertently — to new lands from the ecosystems in which the species evolved.

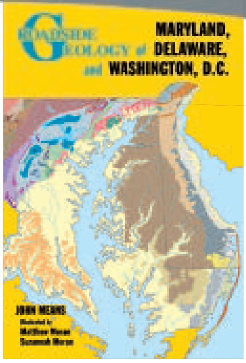
In *The Aliens Among Us*, biologist and science journalist Leslie Anthony chronicles the detrimental effects of invasive species, as well as how these organisms spread and how they can be fought. In the United States, such interlopers — everything from zebra mussels in the Great Lakes to Burmese pythons in the Everglades — damage crops, infrastructure or otherwise cost taxpayers about $145 billion annually.

Invasive species, Anthony writes, are "children born of globalization and consumerism." Their numbers increase as international trade widens and accelerates. Some species surreptitiously hitch a ride to their new homes on human transport: Think seeds and burrs on hikers' clothing, or fish in ballast water of cargo ships. Others have been deliberately released, like earthworms or baitfish set loose by fishermen, or exotic lizards and snakes set free by careless pet owners. Rats, the world's foremost invasive species, have traveled the world with explorers and traders; so have tropical fire ants, which genetic studies suggest have hitchhiked from southwestern Mexico to Asia and beyond starting in the 16th century in soil used as ballast in Spanish ships.

*The Aliens Among Us* is a thoroughly engaging book that draws from Anthony's fieldwork and interviews with scientists, community volunteers, government researchers and policy makers. These groups are struggling to intercept species before they establish a beachhead on new shores, as well as eradicate those that have already gained a foothold. Discussion of people fighting the spread of Zika virus and other exotic diseases — big threats despite their minuscule size — makes the book especially timely.

Some battles against invasives seem almost doomed to fail. Besides the inexorable increase of trade, the inescapable specter of climate change continues to open new vistas for species to colonize (*SN: 12/24/16, p. 23*). *— Sid Perkins*

# GEOLOGIC ROAD TRIP OF THE MONTH




EXCERPT FROM
**ROADSIDE GEOLOGY OF MARYLAND, DELAWARE, AND D.C.**
368 pages • 6x9 • color
$24.00, paper • Item #238
ISBN 978-0-87842-570-9

## WESTERN MARYLAND RAIL TRAIL

The Western Maryland Rail Trail, as of 2010, begins at I-70 exit 12 for Big Pool and parallels the C&O Canal Towpath and the Potomac River for 22 miles up to Pearre (pronounced PAH-ree) in the Sideling Hill water gap. Suitable for cycling, rollerblading, and walking, this nearly flat, asphalt passage offers better access to geologic sites than the towpath because the original Western Maryland Railroad bed had to be cut into the mountains above the towpath in many locations. It also provides access to some classic structures that are not easily reached by automobile. Hancock is a convenient access point, with plenty of parking and services.

At milepost 13 west of Hancock, you can see the remarkable anticlines at Round Top. West of Hancock on MD 144, you can turn onto Locher Road and drive down to the Western Maryland Rail Trail. Walk or bike the asphalt trail about 1 mile west to Roundtop Hill to see what geologist John Glaser called "the best section of folded rocks in Maryland." In the easternmost cut along the old rail bed is an anticline in shale and sandstone of the Bloomsburg Formation, and west of there a syncline and anticline in the Wills Creek Formation. A little farther west, in a second railroad cut, is another anticline in the Wills Creek Formation. Also, you can see numerous openings in Wills Creek limestone beds where rock was mined for the old cement mill, the furnace ruins still in place below the railroad bed.

*At an old railroad cut, now on a bike trail, about 4 miles upstream from Hancock, you can see this symmetrical anticline in the Wills Creek Formation.*

*The Devil's Eyebrow anticline, with eroded layers of Bloomsburg Formation, is uphill from the C&O Canal Towpath at Round Top.*

A third anticline, known as Devil's Eyebrow, is down the hill, about 25 feet above the towpath. An informal, unmarked, steep trail runs down from the east side of the easternmost railroad cut. Calcareous shale and limestone in the Bloomsburg Formation have weathered out in the middle of the arch to form a cave. From the towpath you can also view the kilns of the former, nineteenth-century Round Top Cement Mill.

Between mileposts 18 and 19 are numerous intricately folded Silurian shale beds, small-scale anticlines and synclines within the larger Cacapon Mountain anticline. Near the 20-mile point you can see a classic example of creep in vertically dipping shale of the Devonian Brallier Formation. Creep is an imperceptibly slow form of downslope mass wasting due to gravity and frost heaving. Layers of shale intersecting the steep slope have been bent downslope. If you stop and walk up the dirt road that passes right next to the rail trail here, on the steep slope you can see trees that have been bent as the underlying shale and clay have crept downward.

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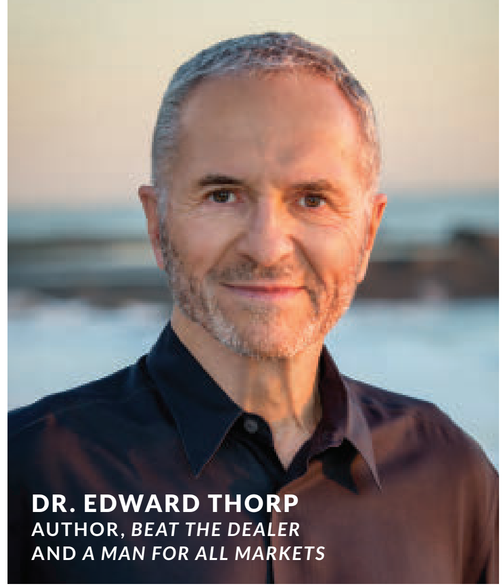
# CONVERSATIONS WITH MAYA



**DR. EDWARD THORP**
AUTHOR, *BEAT THE DEALER* AND *A MAN FOR ALL MARKETS*

Maya Ajmera, President & CEO of Society for Science & the Public and Publisher of *Science News*, sat down to chat with Dr. Edward Thorp — a mathematics professor, inventor, entrepreneur, founder of the first quant hedge fund, blackjack player and the best-selling author of *Beat the Dealer*, the first book to mathematically prove that the house advantage in blackjack could be overcome by card counting. Thorp also published his autobiography, *A Man for All Markets*, earlier this year. We are thrilled to share an edited summary of the conversation.

**In your autobiography, *A Man for All Markets*, you mentioned *Science News-Letter*, now called *Science News*, as having an impact on your education. Can you talk a bit more about the impact that *Science News* has had on your life?**

I grew up in the '40s in California during World War II. Money was scarce. I was going to a high school with very little in the way of academics. I was interested in science, but nobody else there was, so I began teaching myself science. Physics, astronomy, mathematics, chemistry, a little biology — just by reading books and studying on my own. A retired engineer next door gave me a free subscription to *Science News-Letter*, which helped me to understand that there's a whole big world of science and there were many interesting possibilities for working in that world.

**I'm really excited to share that the Society has a program called *Science News* in High Schools that brings *Science News* to more than 4,000 high schools across the country. Through a sponsorship program, the magazine is free to the schools and includes a teaching guide. What advice do you have for students on why reading magazines like *Science News* is so important?**

One of the great things about *Science News* was that it gave me a broader view of science and all the various areas in which scientists were active. It expanded my menu of possible choices. *Science News* also pushed me to gather more general knowledge in science that I might not have had if I hadn't been reading the magazine.

**We were thrilled to see the Science Talent Search included in your life story. Can you talk to me about the impact that competition had on your life?**

A few years before I graduated from high school, I was concerned about finding enough money to go to college, so I delivered newspapers and did other jobs. Then I saw a story in *Science News-Letter* that they had a Science Talent Search contest, and that turned out to be quite a revelation for me. I was fortunate enough to become a finalist and go to Washington, D.C., and really see what the world was like. Because I was a Science Talent Search finalist, it made it easier to get scholarships at whatever university I wanted to go to. I could only afford to go to the University of California because the tuition was minimal at that time, $70 a year. Hard to believe, isn't it? The Science Talent Search was one of the main things that really opened my eyes to the world of science and what it was like.

**Who did you get to meet when you were in Washington?**

It was the first time I ever took a train. The year was 1949, and it was a three-day train ride to Washington, D.C. In the course of my time in Washington, we met Nobel Prize–winner I.I. Rabi, who talked with us at some length, and we visited the 60-inch cyclotron. And then, we had an audience in the Oval Office with President Harry Truman. We all had our pictures taken with him, and he shook each of our hands. I remember his hand very vividly still: It felt like a nicely upholstered, well-used leather armchair with a little talcum powder on it.

MARK JORDAN

Edward Thorp's Science Talent Search class meeting President Harry Truman.

> "**THE SCIENCE TALENT SEARCH** WAS ONE OF THE MAIN THINGS THAT REALLY OPENED MY EYES TO THE WORLD OF SCIENCE."

**We tell all our students who compete in the Science Talent Search, and throughout our competitions, that communications and the humanities are also important. It's part of the creative and intellectual process of being a scientist or a mathematician or an engineer.**

Yes, I have met quite a few great scientists over the course of my lifetime and what I've learned is that the great scientists — for the most part — have a very substantial interest in the humanities. It's interesting that the greater minds have room for both science and the humanities and have a curiosity about both things. I don't know which comes first, but I think it goes both ways. The people who have more talent, more often than not, will be capable in the humanities. This brings a broader perspective in their scientific work.

One thing I've also noticed in interacting with both younger and older scientists is that if a scientist can express him or herself more clearly and cogently, that person becomes much more effective in both conveying what they've done to other people and in working together with other people. It is very valuable to be able to speak clearly, distinctly and cogently.

**What was it about the humanities that got you excited?**

I had one remarkable English teacher who taught American literature. One summer, he lent me 60 books — I spent the summer between my junior and senior years sitting on the beach reading and bodysurfing. There were things like *The Brothers Karamazov*, *Of Mice and Men*, *The Jungle* and Sinclair Lewis' *Arrowsmith*. It was a revelation in my view of the world, and it enormously enlarged my vocabulary.

**Switching gears, you are well known for your blackjack skills; you even wrote a best-selling book called *Beat the Dealer* in the '60s. Where did your interest in blackjack begin and are you still playing today?**

Well, I got interested in blackjack, you might say, purely by chance. I got interested in applying physics to predicting the outcome of a roulette spin. I went to Las Vegas for a vacation after I got my Ph.D. in math because I wanted to observe roulette wheels. While I was there, I happened to play a little blackjack. After playing for about 40 minutes, I saw how you could beat the game, and it turned out I was right. And that's how I came to write what turned out to be a *New York Times* best-selling book on card counting at blackjack. It was the first book of that type, and it led large numbers of people to head to the casinos in Las Vegas. It also caused the casinos to try to change the rules, unsuccessfully.

**Dr. Thorp, you have had an unbelievably varied and storied career. You were a professor of math, you're a blackjack guru, you created a hedge fund, you developed the first wearable computer; most people just do one of those things in their lifetime and are pretty content. What are the key lessons you've learned from having such a diverse and unique career path?**

Well, what was the handicap for me in junior high and high school — having to teach myself and not having any mentors or academic courses of any value — also proved to be a benefit because I learned to think through things for myself. If something came up, like "can you beat gambling games," and everybody would say, "No, you couldn't," I wouldn't accept that. I would say, "Well, I'll check it out for myself and see what I think."

So I didn't go with conventional wisdom most of my life. I just simply tried to think independently, and I wanted things that were evidence-based.

I'd also like to add that one of the most common things that people ask me is, what should I do to become successful in science, finance, gambling? I tell them not to start out with some goal, like trying to make money. Instead, figure out what it is you like to do, because the activity that you do — call it work, but it won't be work if you choose it right — the activity that you do is going to be a very large part of your life and you want to be happy doing it. So choose something that will make you happy and it's probably something that you're good at. And then, just follow your dreams in that direction and you'll more than likely find out that everything will work out very well for you. It's the people who try to go against what they really want to do that end up being so unhappy. ◆

SEPTEMBER 30, 2017

## Gut feelings

*Tests in mice show that microbes in the gut may tamper with the production of tiny molecules in brain regions known to help control anxiety,* ***Maria Temming*** *reported in "How gut bacteria may affect anxiety"* (SN: 9/30/17, p. 12).

Online reader **Amanda** wondered what has more influence: gut bacteria on anxiety, or anxiety on the bacterial makeup of the gut. If bacteria have more of an effect on anxiety, she asked whether it could be treated with diet rather than drugs.

Researchers are still working out the details of the gut-brain connection, says **Gerard Clarke**, a psychiatrist at University College Cork in Ireland. Tweaking the gut's microbial population can affect anxious behaviors, animal studies have shown, which suggests that gut bacteria could play a causal role in anxiety. But other research has indicated that various stressors can alter the composition of the gut microbiota. It's "difficult to tease apart which has the most influence," **Clarke** says.

If bacteria do influence anxiety, the right diet may be able to help. "Diet is considered one of the main factors that shape the gut microbiota," **Clarke** says. Studies hint that proper diet could help treat depression, "but there is less data specifically related to anxiety at the minute," he adds. So it's "too early to say if this will generalize to psychiatric disorders other than depression."

## Spare ribs

*Fossil evidence suggests that some woolly rhinos may have been at a high risk for sprouting bizarre ribs from their necks before going extinct, a potential result of inbreeding,* ***Susan Milius*** *reported in "Some woolly rhinos grew odd neck ribs"* (SN: 9/30/17, p. 10).

Online reader **stp** suggested that the ribs could have evolved as protection against predators that bite through the neck.

That's unlikely in this case. Woolly rhinos had massive, muscular necks covered by dense fur, which meant that predators would have needed long, daggerlike canines to bite through, says paleontologist **Alexandra van der Geer** of Naturalis Biodiversity Center in Leiden, the Netherlands. The extinct beasts' Ice Age predators were wolves and a type of stocky hyena. "They hunt their prey to exhaustion and simply bite at whatever part they can get hold of," she says. "Evisceration is then the cause of collapse, not a bite in the neck."

## If it looks like a horse

*A study of ancient extinct horses revealed why equines shed their toes in favor of single hooves,* ***Emily Underwood*** *reported in "Horses traded toes for speed, strength"* (SN: 9/30/17, p. 12).

Reader **David Campbell** asserted that fossilized horses in the study belonging to the group *Hyracotherium* aren't horses at all.

"It's complicated," says study coauthor **Brianna McHorse**, a paleontologist at Harvard University. Researchers go back and forth on whether or not to classify *Hyracotherium* as horses. Currently, there's only one accepted species of *Hyracotherium*, and it isn't considered a horse, though that's controversial, she says. Several horse species that once belonged to the *Hyracotherium* genus now belong to different genera. Those are the species that **McHorse** and colleagues analyzed. The specimens are certainly horses, she says. In the study, the researchers referred to the species by their original *Hyracotherium* name.

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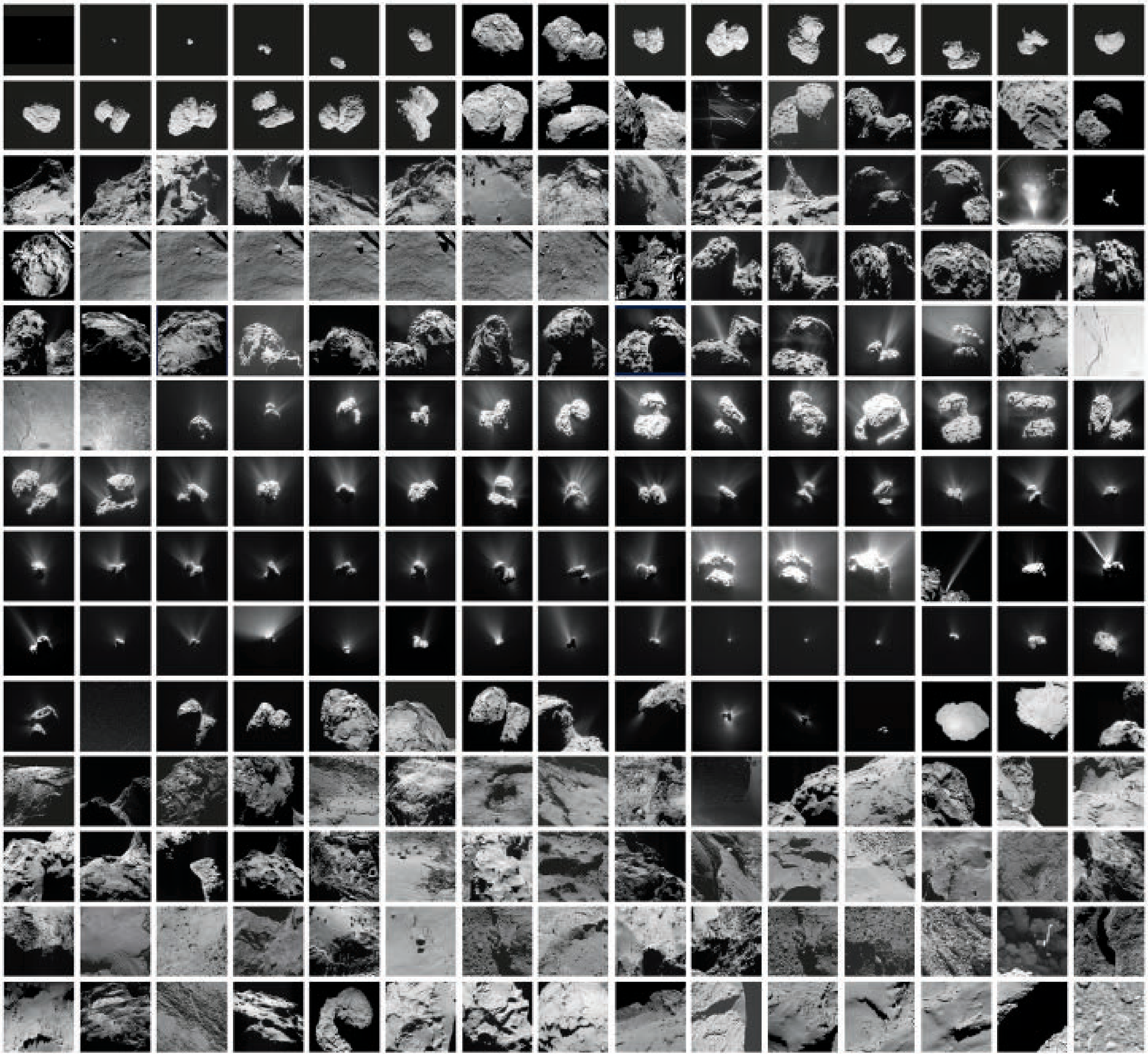



# A reminiscence of Rosetta

A year after the Rosetta spacecraft's rendezvous with comet 67P/Churyumov-Gerasimenko came to an end, the views are still stunning. This montage, released in September by the European Space Agency, includes 210 of the thousands of images taken by Rosetta and the Philae lander and recaps the daring mission to explore the space rock. The images are arranged chronologically (starting at the top left and moving from left to right in each row).

After a decade-long journey to catch up to a comet whizzing through space at speeds up to 135,000 kilometers per hour, Rosetta finally reached 67P in August 2014 (*SN: 9/6/14, p. 8*). The spacecraft began documenting the comet's odd duck shape (*SN: 2/21/15, p. 6*) and zooming in to pinpoint a perfect place for Philae to park. Each craft took "farewell" images of the other before Philae's tumultuous touchdown, when the lander got an extremely close look at the comet's surface (fourth row).

Rosetta captured its shadow on 67P's surface (sixth row, far left), along with evidence of outgassing from the comet. The spacecraft then drew close enough to spot Philae (second to last row, second from right) and snap extraordinary views of the surface before making its own final plunge into the comet on September 30, 2016. The last image in the mosaic shows the spot on 67P's surface that became Rosetta's final resting place. *—Ashley Yeager*

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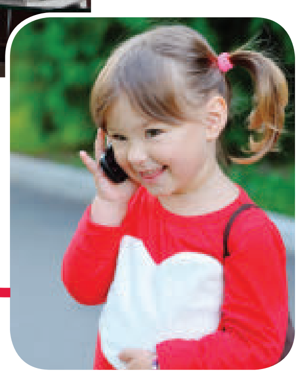

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