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SCIENCE NEWS MAGAZINE
SOCIETY FOR SCIENCE & THE PUBLIC
OCTOBER 28, 2017

Pesticides Turn Up in Honey

Pluto Is Ringless After All

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# Blood Feeders

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# ScienceNews


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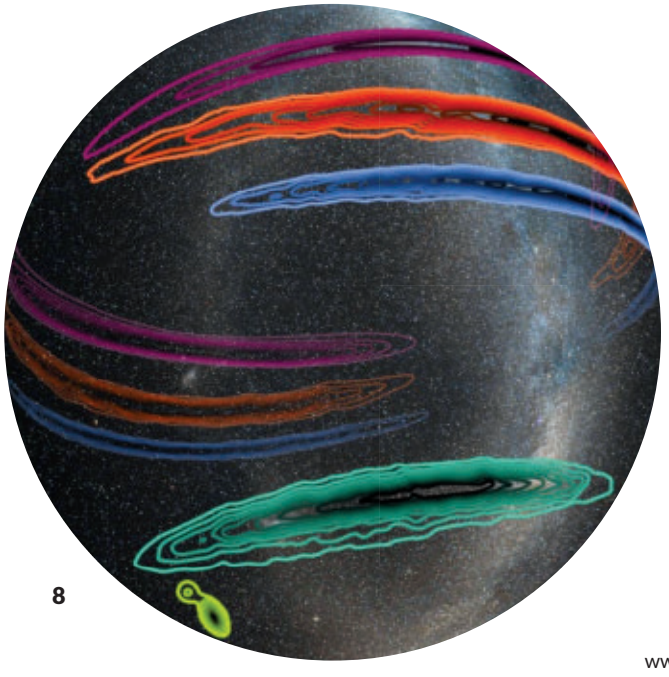
## Features



## News

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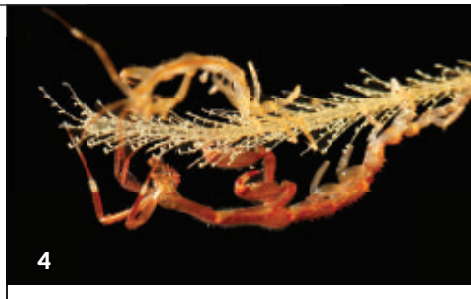
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## Departments



**SOCIETY UPDATE**
Give to Science Day is coming soon

**COVER** Blood-hungry parasitic lampreys, tsetse flies, birds and bats have various ways of procuring meals. *Matt Griffin*

FROM TOP: ANDREANITA/ALAMY; HANS HILLEWAERT/WIKIMEDIA COMMONS (CC BY-SA 4.0); LEO SINGER/LIGO, MIT, CALTECH, VIRGO, AXEL MELLINGER (MILKY WAY IMAGE)

# Conspiring with engineers helps make science great

From what I can tell, there's a fair amount of friendly rivalry between folks who call themselves "scientists" and those who call themselves "engineers." Bill Nye, educated as a mechanical engineer, had to defend himself as the "Science Guy" on *The Late Show with Stephen Colbert* earlier this year: "It's physics, for four years, it's physics," he said. Dean of the Boston University College of Engineering, Kenneth R. Lutchen, has adamantly declared that "Engineers are not a subcategory of scientists," going on to lament the fact that a 2010 *Time* magazine story about Thomas Edison used the word *science* many more times than *engineering*. And let's not forget T-shirts with bold claims like: "Scientists dream about doing great things, engineers do them." Ouch.

But I suspect, when asked, both scientists and engineers would readily admit that they rely on each other. Many of the best collaborations call on the skills of both. That's definitely the case for the detection of gravitational waves, which won researchers from Caltech and MIT the 2017 Nobel Prize in physics (Page 6). Albert Einstein had predicted gravitational waves a century ago; the trick was to figure out how to build an interferometer sensitive enough to detect changes measuring a tiny fraction of the diameter of a proton. I'm not the first person to call it an impressive feat of engineering. No doubt the development of cryo-electron microscopy, the topic of this year's chemistry Nobel, also required an engineering perspective. It took improved optics, detectors and computational techniques to boost the resolution of what many had called "blobology." Those are just two examples of many. Consider where astronomy would be without improvements in the telescope, or where studies of past climate would be without drilling technologies to pull up gigantic sediment cores. And what about genetic engineering? No field is hotter right now.

Though science is more about acquiring knowledge and engineering more about applying it, the two passions often coexist in the same individual. Engineers possess the spirit of discovery, too. And a lot of scientists harness their findings for the betterment of humankind. — *Elizabeth Quill, Acting Editor in Chief*

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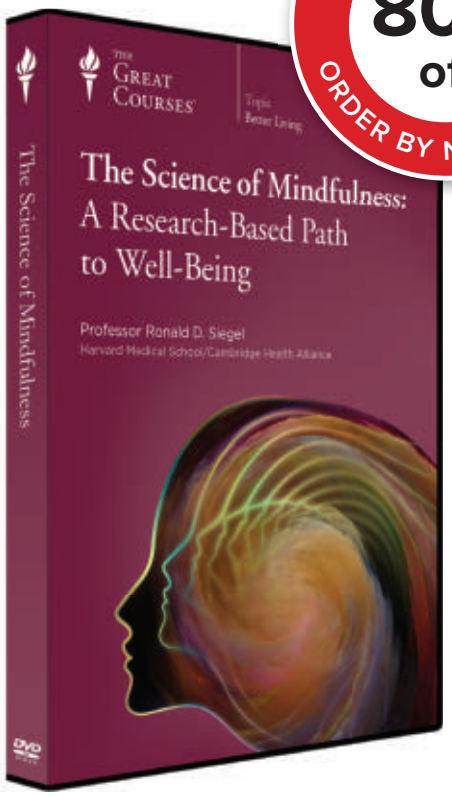


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Excerpt from the October 28, 1967 issue of *Science News*

50 YEARS AGO

## Net to halt runaway airliners

A gigantic emergency arresting gear system, capable of stopping the largest four-engined jet aircraft without discomfort to passengers, is being developed for the French Ministry of Transportation. The system consists of a nylon net ... which engages the aircraft for the full width of its wingspan. Net and airplane are brought to a slow stop by energy absorbing devices located along the sides of the runway.

**UPDATE:** Catching commercial airliners in giant nets never took off. However, aircraft carriers have deployed nylon nets since 1931 for emergency landings. In modern versions, nets are linked to energy-absorbers below deck to help bring a plane to a safe stop. Today's net systems are a big improvement over the original barricade: Aviation pioneer Eugene Ely first landed an airplane on a ship, the *USS Pennsylvania*, in 1911. His landing relied on sandbag-secured ropes across the deck plus a canvas awning between the plane and the sea.




THE LIST

## Castaway critters rafted to U.S. shores on Japan tsunami debris

The 2011 tsunami that devastated Japan's east coast cast an enormous amount of debris out to sea — way out. Marine life took advantage of the new floating real estate and booked a one-way trip to America. From 2012 to 2017, at least 289 marine species washed up on the U.S. Pacific coast and Hawaii, hitching rides on fishing boats, docks, buoys and other nonbiodegradable objects, a team of U.S. researchers reports in the Sept. 29 *Science*. Organisms that survived the harsh 7,000-kilometer journey across the Pacific Ocean on 634 items of tsunami debris ranged from a 52-centimeter-long fish (a Western Pacific yellowtail amberjack) to microscopic single-celled protists. See Page 32 for a breakdown of species by taxonomic group. — *Mariah Quintanilla*

**Meet a few of the travelers:**

- **Skeleton shrimps** 1 (*Caprella mutica*, shown, and four other species) grasp algae with strong rear claws, earning them the nickname "praying mantis of the sea."
- **Northern Pacific sea stars** 2 (*Asterias amurensis*) are among the world's worst invasive species.
- **Japanese barred knifejaw fish** 3 (*Oplegnathus fasciatus*) made a two-year trip trapped in the stern well of a Japanese fishing boat that beached in 2013 in Washington (actual fish shown).
- **Bryozoa** (*Biflustra grandicella*), or moss animals, are microscopic filter feeders that live in surface-sticking colonies.
- **Japanese shipworms** (*Psiloteredo* sp.) are wood-boring, wormlike mollusks; some had grown about 50 centimeters long.

FROM TOP: HANS HILLEWAERT/WIKIMEDIA COMMONS (CC BY-SA 4.0); LYCOO/WIKIMEDIA COMMONS; A. PLEUS

At the La Brea Tar Pits in today's Los Angeles, mastodons, dire wolves, saber-toothed cats and thousands of other creatures — prey and predators — were trapped and later excavated.

THE SCIENCE LIFE

## A modern diagnosis of an ancient cat

Robert Klapper has examined scores of damaged and diseased human knees, hips and shoulders. But a visit to the La Brea Tar Pits and Museum introduced the orthopedic surgeon to the suffering of an extinct cat — and a scientific mystery. In 2000, Klapper took a break from his patients at Cedars-Sinai Medical Center in Los Angeles to visit the nearby tar pits, where myriad mammals and other animals (*SN: 5/17/14, p. 18*) have been getting stuck for the last 40,000 years. (Yes, modern birds and insects still wander in.)

After examining a museum display of broad-snouted dire wolf (*Canis dirus*) skulls, Klapper made a beeline for the security guard and asked to see a curator. He badgered then collections manager Chris Shaw with questions about why the skulls looked so perfect — no signs of cancers, fractures or arthritis.

"Instead of throwing me out," Klapper says, Shaw took Klapper into the bowels of the museum and pulled out a drawer of bones from saber-toothed cats (*Smilodon fatalis*), one of the abundant prehistoric animals preserved in the pits about 14,000 years ago. Klapper noticed a pelvis with a surface that reminded him of a medieval mace: One hip socket was spiky with sharp edges, a telltale sign of arthritis. At the healthy hip socket, the bone was billiard ball smooth.

A cratered saber-toothed cat pelvis (top) shows signs of hip dysplasia. The pelvis and disfigured head of the femur (bottom) are undergoing new scrutiny.

That kind of bone damage did not happen overnight. The arthritic animal had been disabled for years, Klapper estimated, perhaps even from birth. The surgeon asked a favor: "I'd love to get a CT scan." Signing out the ancient cat's pelvis, he says, was a thrill.

Paleontologists have long debated whether saber-toothed cats were solitary or social hunters. If this lame cat had been unable to hunt for years, which is what its traumatized hip bone indicated to Klapper, it could have survived only with help from other cats.

Klapper scanned that fossilized cat pelvis but left the images untouched for years, occupied with his hospital job and hosting ESPN Radio's *Weekend Warrior*, a health and sports program. Now, collaborating with Emily Lindsey, a paleoecologist at La Brea, Klapper plans to use more sophisticated radiology techniques to diagnose the deformity and possibly deduce clues about the cat's lifestyle.

It's still early days for the revitalized project, Lindsey cautions, but "I'm really excited about it." The museum houses some 2,000 fossils of saber-toothed cats, several of which the two plan to scan in the months ahead.
*— Lesley Evans Ogden*

SCIENCE STATS

## Concussions are common in teens

Nearly 1 in 5 adolescents has suffered at least one concussion, according to a survey of U.S. teens. And 5.5 percent reported two or more concussions diagnosed in their lifetimes, researchers report in the Sept. 26 *JAMA*.

About 13,000 eighth-, 10th- and 12th-graders participated in the 2016 Monitoring the Future survey, an annual national questionnaire of adolescent behavior and health given in schools. Among other questions, teens were asked whether they had ever had a head injury that was diagnosed as a concussion — 19.5 percent replied "yes." Those teens were more likely than others to play competitive sports and be male, white and in a higher grade.

Previous studies have found that kids taking part in contact sports are at higher risk of suffering a concussion. These new data on actual prevalence of concussions, though self-reported, are important, say the authors, for crafting prevention efforts that protect teens from injuries. *— Aimee Cunningham*

**19.5**
percent
U. S. teens reported at least one concussion

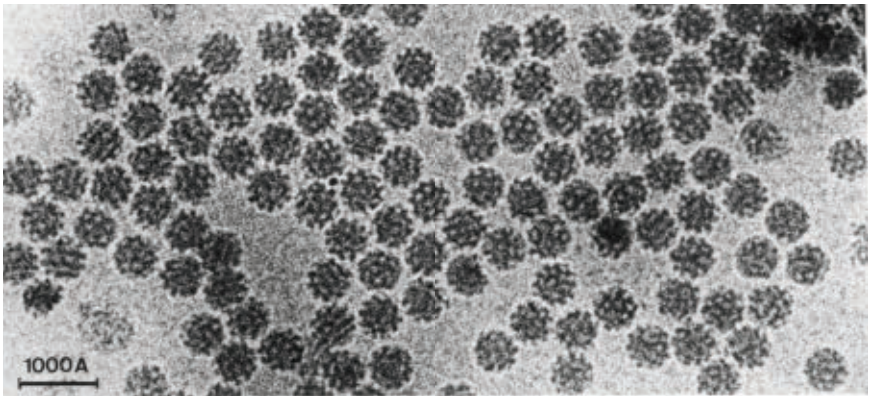
**5.5**
percent
U. S. teens had two or more concussions

FROM TOP: LARISSA PEREIRA/SHUTTERSTOCK; E. LINDSEY

SCIENCE & SOCIETY

# New views snag science Nobels

## Economics prize awarded for insights into decision making




This year's chemistry Nobel Prize honors the developers of cryo-electron microscopy. In 1984, Jacques Dubochet used a thin layer of flash-frozen water to protect this sample of Semliki Forest virus from dehydration in the vacuum of an electron microscope. Each virus's width is roughly 500 angstroms, or 50 nanometers. That technique became a key component of cryo-EM.

Discovering the molecular gears in the body's circadian clock, detecting gravitational waves and creating a way to peer into the minuscule structures of biomolecules have all brought nature's mysteries into better focus — and nabbed researchers this year's Nobel Prizes in science.

Jeffrey C. Hall and Michael Rosbash, of Brandeis University in Waltham, Mass., and Michael W. Young of Rockefeller University in New York City received the prize in physiology or medicine for their work on the molecular ups and downs of fruit flies' daily lives. The researchers identified key components of circadian clocks, the networks of genes and proteins that govern daily rhythms and cycles such as sleep, the release of hormones, the rise and fall of body temperature, and other bodily processes.

"An awful lot of what was subsequently found out in the fruit flies turns out also to be true and of huge relevance to humans," says John O'Neill, a circadian cell biologist at the MRC Laboratory of Molecular Biology in Cambridge, England.

These findings have helped explain why long-term jet lag, experienced by shift workers and others whose circadian rhythms are thrown out of whack, is linked to serious health consequences. Identifying the molecular underpinnings of circadian clocks has opened the door to finding treatments for these diseases.

The method honored by the chemistry prize may also lead to new therapies. Jacques Dubochet of the University of Lausanne in Switzerland, Joachim Frank of Columbia University and Richard Henderson of the MRC Laboratory of Molecular Biology each played a role in the development of cryo-electron microscopy. The 3-D imaging technique, also known as cryo-EM, freezes biological molecules and viruses in place to view their structures at the scale of atoms.

Over decades of work, the researchers contributed innovations that have allowed cryo-EM to map the minute landscapes of proteins and other biomolecules at scales as tiny as tenths of a nanometer, and to help decipher their functions. In 2016, scientists used cryo-EM to map the Zika virus, helping to identify possible regions to target with a vaccine or antiviral drugs (*SN: 4/30/16, p. 10*).

The 2017 physics prize recipients have also ushered in a new era of observation. Rainer Weiss of MIT and Kip Thorne and Barry Barish, both of Caltech, are pioneers of the Advanced Laser Interferometer Gravitational-Wave Observatory, or LIGO. On February 11, 2016, LIGO scientists announced they had spotted gravitational waves produced by a pair of merging black holes. Since that first detection, scientists have observed three more black hole collisions (see Page 8).

LIGO's data confirmed a prediction of Einstein's general theory of relativity — that rapidly accelerating massive objects stretch and squeeze spacetime, producing ripples that travel outward from the source (*SN: 3/5/16, p. 22*). LIGO is expected to spark a new field of astronomy. "It will allow us to see the parts of the universe that were not revealed to us before," says LIGO team member Carlos Lousto of the Rochester Institute of Technology in New York.

In the week following the science prize announcements, Richard Thaler of the University of Chicago was announced as the winner of the 2017 Nobel Memorial Prize in Economic Sciences. Thaler is recognized for leading a discipline that has championed the idea that people are not purely rational and selfish — as long posited by economists. Instead, he argues, we are driven by simple, often emotionally fueled assumptions that can lead us astray. — *Bruce Bower, Emily Conover, Aimee Cunningham, Carolyn Gramling, Lisa Grossman, Laurel Hamers and Tina Hesman Saey*

**2017 Nobel Laureates**

PHYSIOLOGY OR MEDICINE
**Jeffrey C. Hall**
*Brandeis University*
**Michael Rosbash**
*Brandeis University*
**Michael W. Young**
*Rockefeller University*

PHYSICS
**Rainer Weiss**
*MIT*
**Barry Barish**
*Caltech*
**Kip Thorne**
*Caltech*

CHEMISTRY
**Jacques Dubochet**
*University of Lausanne*
**Joachim Frank**
*Columbia University*
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ECONOMIC SCIENCES
**Richard Thaler**
*University of Chicago*

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# Networking was key to human success

## Social structure distinguished ancient people from Neandertals

**BY BRUCE BOWER**

DNA of people who lived around 34,000 years ago reveals an especially lively social scene that may have been a key to humans' evolutionary success.

Much like hunter-gatherers today, ancient Eurasians married outside their home groups and formed webs of friends and in-laws vital for eventually building cities and civilizations, a new study suggests.

Long-gone hunter-gatherers lived in groups with few close relatives, thus limiting opportunities for inbreeding, say evolutionary geneticist Martin Sikora of the Natural History Museum of Denmark in Copenhagen and colleagues. Adolescents of both sexes probably found mates in communities other than their own, fostering social ties among groups that might otherwise avoid or fight each other, the scientists conclude online October 5 in *Science*. Modern hunter-gatherers likewise find partners among nearby groups.

The new findings support a proposal that hunter-gatherer bands composed mainly of in-laws and unrelated individuals appeared by the late Stone Age and probably much earlier than that, says anthropologist Kim Hill of Arizona State University in Tempe. The emergence of in-laws boosted communication and social learning across groups, a prerequisite for creating civilizations.

"Hunter-gatherer social structure is apparently unique to humans and is the reason why we alone are so reliant on culture and have achieved the marvels of technology and human society," Hill says.

The new study undercuts a long-standing idea that Stone Age hunter-gatherers clustered among close kin, with men forming alliances and guarding home territories against competing groups, much as chimpanzees do. If true, then the spread of agriculture 10,000 years ago may have been what led modern hunter-gatherers to develop extensive social networks. But Sikora and colleagues' study "shows that modern humans already lived in socially fluid societies well before the origins of agriculture," says anthropologist Andrea Migliano of University College London.

Living in small, interacting groups consisting mainly of those who weren't kin made sense for people roaming near-Arctic parts of Europe and West Asia starting around 40,000 years ago, says paleoanthropologist and study coauthor Marta Mirazón Lahr of the University of Cambridge. Those hunter-gatherers had to forage over large areas to survive, and mate exchanges among groups minimized inbreeding, she contends.

Skeletons of four people buried at a western Russian site called Sunghir provided DNA for the new analysis. These individuals include a man in his own grave and two preteens or early adolescents placed head-to-head in the same grave, near a piece of an adult's upper leg bone filled with a red pigment. Both graves included fancy items such as ivory beads and spears, armbands and carvings. Researchers have excavated Sunghir intermittently since the 1950s.

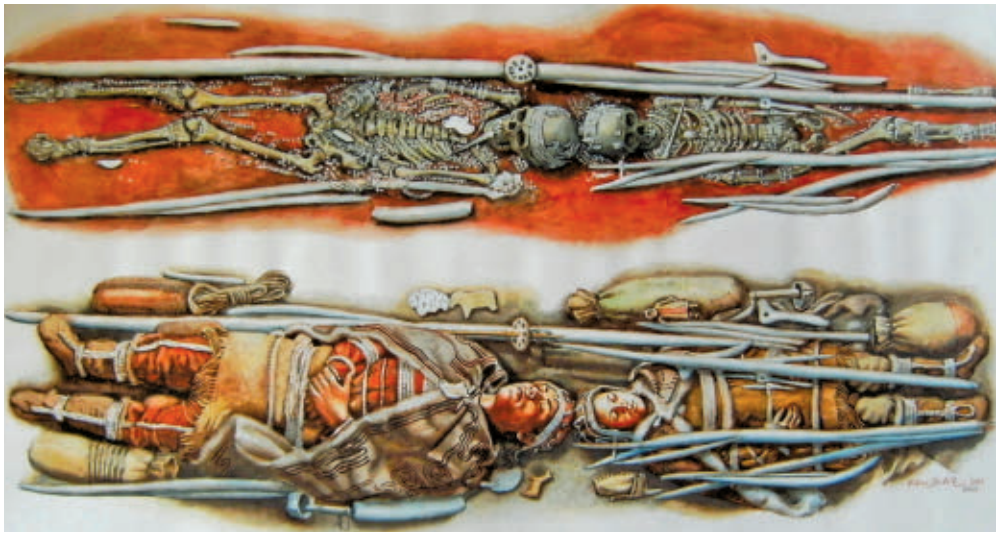
New radiocarbon dates for the fossils and a mammoth bone found at the site gave a more precise date for the Sunghir burials than was previously available.

Ancient DNA from the four Sunghir individuals includes parts of the sex chromosomes, indicating that all of the skeletons were male. Genetic comparisons found no parent, grandparent, sibling, uncle or nephew relationships.

Analysis of a largely complete set of genetic instructions from one Sunghir youngster suggests that he came from a population that split off around 38,000 years ago from direct ancestors of modern Europeans. That ancient Sunghir-related population was small, with anywhere from about 160 to 900 procreating adults, the scientists estimate.

In rough agreement with previous estimates for present-day Europeans and East Asians, Sunghir individuals inherited about 2.5 percent of their DNA from Neandertals, Sikora's team finds. That interbreeding occurred around 55,000 years ago, the investigators calculate. Further cross-species flings 36,000 years ago contributed nearly another 0.4 percent Neandertal DNA to the Sunghir group.

Sunghir people did not display genetic markers of inbreeding as previously observed in Neandertal DNA (*SN: 1/25/14, p. 17*). Neandertals lacked mating networks like those of ancient humans, the researchers propose. ■



LIBOR BALÁK, ANTROPARK

DNA from four Stone Age people — including two illustrated here as they looked when excavated (top) and at burial (bottom) — suggests that hunter-gatherers have long formed groups with few close relatives. That social structure reduced inbreeding and encouraged intergroup cooperation.

ATOM & COSMOS

# Trio tracks source of gravity waves

## LIGO, Virgo detectors team up to capture black hole collision

**BY EMILY CONOVER**

The gravitational wave paparazzi have tracked down the cosmic neighborhood of two merging black holes. Scientists pinpointed the region in the sky where the two black holes violently melded and kicked up swirls of the spacetime ripples, locating their stomping grounds more precisely than ever before.

Researchers from the Advanced Laser Interferometer Gravitational-Wave Observatory — LIGO — and its sister experiment, Advanced Virgo, spotted the ripples on August 14. The team announced the finding September 27 at a news conference at a meeting of the G7 science ministers in Turin, Italy, and in a paper accepted in *Physical Review Letters*.

It's the first gravitational wave sighting to be made with three detectors: LIGO's two detectors (in Livingston, La., and Hanford, Wash.) and Virgo's detector near Pisa, Italy. "The three-detector network really opens up a new potential and we are going to make the most of that potential in the future," said Virgo scientist Frédérique Marion of the Laboratoire d'Annecy de Physique des Particules in France.

The trio of detectors allowed scientists to trace the source of the gravitational waves to a spot in the sky with an area of just 60 square degrees. Viewed in the night sky, the size of that region is about 300 times that of the full moon as seen from Earth. The ripples journeyed to Earth from about 1.8 billion light-years away, in a region near the constellation Eridanus in the southern sky.

Starting in 2015, LIGO has previously detected three black hole crashes with its two detectors; in each case, scientists carved out a swath of sky from which the waves could have come, but could not discern a more specific cosmic birthplace. The newfound black holes were located within a region about a tenth the size of those associated with previous detections.

Because gravitational waves take time to complete the cross-planet jaunt from one detector to another, the three detectors spotted the signal at slightly different times. LIGO's Livingston detector saw the waves first, followed by the LIGO Hanford detector eight milliseconds later, and by the Virgo detector another six milliseconds after that. By analyzing these delays and the patterns of the ripples each detector saw, scientists were able to deduce what direction the ripples came from.

Scientists estimated the colliding black holes' masses at about 31 and 25 times the sun's mass. During the collision, approximately three solar masses were converted into energy and radiated as gravitational waves, leaving behind a 53-solar-mass black hole.

The LIGO and Virgo detectors teamed up August 1 (*SN Online: 8/1/17*), when Virgo began officially taking data for the first time in its current, upgraded form. Previous incarnations of both LIGO and Virgo ran for years without detecting a whiff of spacetime wiggles. Now the detectors are finally sensitive enough to pick up the tiny tremors. The improved trio operated in tandem until August 25, when the detectors shut down for further improvements.

Virgo also allowed scientists to better test Einstein's general theory of relativity. Because Virgo's detector isn't oriented parallel to the LIGO detectors, scientists could study the polarization of the waves — the specific pattern by which they stretch and squeeze spacetime — for the first time.

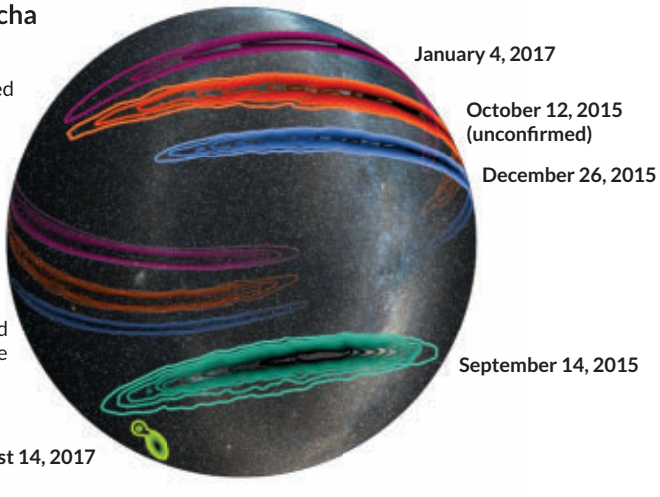
"In the long run that's a really big deal," says physicist Clifford Will of the University of Florida in Gainesville, who was not involved with the detection. If unexpected kinds of stretching or squeezing were found, "it would kill general relativity, just like that. That would be the end." But Einstein's theory held its ground.

Scouting out the locales where black hole pairs live allows astronomers to look for light produced in the collision. Although most scientists expect that no light will be emitted in black hole dust-ups, some theories suggest otherwise. After the ripples were detected, telescopes scoured the spot, but observations came up empty.

Other kinds of collisions, however — between two remnants of stars called neutron stars — could produce light. Therefore, the new detection "is good preparation for what's to come," says physicist Emanuele Berti of the University of Mississippi in Oxford, who was not involved with the detection. Spotting light from a neutron star pileup could help scientists learn more about the extremely dense material that makes up neutron stars. In August, rumors began flying that scientists had detected such an event (*SN Online: 8/25/17*). ■

### Gravitational gotcha

With the August 14 detection of spacetime ripples, scientists homed in on the location of gravitational wave–flinging black holes more precisely than ever before, illustrated in lime green on this map of the sky. The regions associated with three previous detections and an unconfirmed hint are shown for comparison.




LEO SINGER/LIGO, MIT, CALTECH, VIRGO, AXEL MELLINGER (MILKY WAY IMAGE)

GENES & CELLS

# Zika mutation linked to microcephaly

## Small change in one protein might explain surge in birth defects

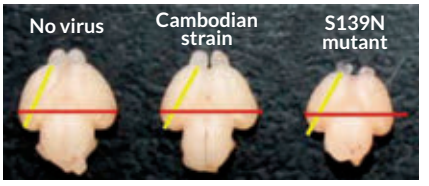
**BY TINA HESMAN SAEY**

A single genetic mutation made the Zika virus far more dangerous by enhancing its ability to kill nerve cells in developing brains, a new study suggests.

The change — which tweaks just one amino acid in a protein that helps Zika exit cells — may cause microcephaly, researchers report online September 28 in *Science*. The mutation arose in 2013, the researchers calculate.

Zika was discovered decades ago but wasn't associated with microcephaly — a birth defect characterized by a small head and brain — until the 2015–2016 outbreak in Brazil. Women who contracted the virus while pregnant started giving birth to babies with the condition at higher-than-usual rates (*SN: 4/2/16, p. 26*).

Researchers weren't sure why microcephaly suddenly became a complication, says Pei-Yong Shi, a virologist at the University of Texas Medical Branch in Galveston. Maybe the virus caused microcephaly before, scientists suggested, but at such low rates that no one noticed. Or maybe people in South America are more vulnerable to Zika. But Shi and colleagues in China thought the problem might be linked to changes in the virus itself.




A strain of Zika isolated in Cambodia in 2010 and injected into fetal mouse brains caused a slightly smaller brain (middle) than normal (left). A mutation that arose in the virus in 2013 led to even smaller brains (right).

The team compared a Zika strain isolated from a patient in Cambodia in 2010 with three strains from patients who contracted the virus during the 2015–2016 epidemic. The team found seven common differences between the Cambodian virus and the three epidemic strains.

Researchers engineered seven versions of the Cambodian virus, each with one of the epidemic strains' mutations, and injected the viruses into fetal mouse brains. Viruses with one of these mutations, dubbed S139N, killed brain cells in fetal mice and destroyed human brain cells grown in lab dishes more aggressively than the 2010 strain did.

"That's pretty convincing evidence that it at least plays some role in what we're seeing now," says Anthony Fauci, director of the National Institute of Allergy and Infectious Diseases in Bethesda, Md.

The mutation changes an amino acid in a Zika protein called prM, which helps the virus mature within infected cells and get out to infect others. Shi's group doesn't know why tweaking the protein makes the virus kill brain cells more readily.

Brain cells from different people vary in their susceptibility to Zika, says infectious disease researcher Scott Weaver, also at the University of Texas Medical Branch but not involved in the study. He says more work on human cells and in nonhuman primates is needed to confirm whether this mutation is really a culprit in microcephaly. ■

EARTH & ENVIRONMENT

# Jungles are now carbon emitters

## Close look at world's tropical forests reveals loss of density

**BY CAROLYN GRAMLING**

The world's tropical forests are exhaling — and it's not a sigh of relief. Instead of soaking up climate-warming gases on balance, these so-called "lungs of the planet" are beginning to release them.

A new study based on analyses of satellite imagery of tropical Asia, Africa and the Americas suggests that tropical forests contribute more carbon dioxide to the atmosphere than they remove. Much of that carbon contribution is due to deforestation. But more than two-thirds comes from a less visible source: a decline in the number and diversity of trees and other vegetation in remaining forests, researchers report online September 28 in *Science*.

Tropical forests are a bulwark against rising $CO_2$ in the atmosphere, taking up carbon and storing it as stems, leaves and roots. Deforestation's effect is clear; it cuts the number of trees that take up $CO_2$. But even seemingly intact forests can be degraded by selective logging, environmental change, wildfires or disease.

Unlike deforestation, degradation can be hard to spot by satellite, says Alessandro Baccini, a forest ecologist and remote-sensing specialist at the Woods Hole Research Center in Falmouth, Mass. A degraded forest still looks like forest — it's just less dense, with less carbon biomass.

To estimate carbon density, Baccini and colleagues came up with a way to calibrate satellite images of the tropics using field observations and NASA Light Detection and Ranging Data, or lidar. Then, the team created an algorithm that compares 500-meter-square parcels of each image from each year from 2003 to 2014 to calculate gains and losses in carbon density.

In total, tropical forests emit about 862 teragrams of carbon annually — more than all cars in the United States did in 2015 — and absorb only about 437 teragrams each year. Of that net loss, 69 percent is from degraded forests and the rest from deforestation.

Terrestrial ecosystem scientist Joshua Fisher of NASA's Jet Propulsion Laboratory in Pasadena, Calif., notes that the results don't fully gel with atmospheric observations, which still show that tropical forests take up more carbon than they emit. That discrepancy may be because the new study focuses on aboveground biomass, not what's absorbed in soils, he says. Still, Fisher says, the study shows how important it is to include forest degradation in climate change studies. ■

L. YUAN ET AL/SCIENCE 2017

Some *Cassiopea* jellyfish regularly enter a sleeplike state, a new study finds.

LIFE & EVOLUTION

# Upside-down jellyfish pass sleep test

## Slumber may be a fundamental requirement of animal life

**BY MARIAH QUINTANILLA**

The life of a jellyfish may seem like a real snooze, but biologists have been uncertain if the gelatinous blobs actually sleep. Now it appears that at least one group of jellyfish needs its beauty rest just like us.

Some species of upside-down jellyfish (*Cassiopea*) meet all of the criteria for entering a "sleeplike state," a group of Caltech researchers reports online September 21 in *Current Biology*. The jellyfish seem groggy after a sleepless night and quickly waken from their slumber when fed, experiments show.

It's a surprising find: Sleep and sleeplike states have been documented in a wide range of animals — from microscopic wormlike nematodes to, of course, humans (*SN: 10/24/09, p. 16*). But until now, the behavior has been observed only in animals with a centralized nervous system and brain.

Jellyfish operate on a decentralized net of nerve cells. "It's the first animal that doesn't have a centralized nervous system that also sleeps, that we know of," says study coauthor and biologist Ravi Nath. Adds coauthor Michael Abrams: "Sleep is not solely generated by animals with brains."

The finding raises new questions about when — and why — sleep evolved. Jellyfish are cnidarians, an ancient animal lineage that evolved at least 600 million years ago. So if *Cassiopea* jellyfish in fact sleep, it suggests that sleep is one of the most basic requirements of animal life. And unlike in humans, where sleep has been linked to such brain functions as retaining memories, the same can't be said of the role of sleep for jellyfish.

> "Sleep is not solely generated by animals with brains."
>
> MICHAEL ABRAMS

"Finding sleep in jellyfish thus raises the question of whether sleep and nervous system functions are intertwined," says William Joiner, a neuroscientist at the University of California, San Diego, "or, alternatively, whether sleep arose before the inception of the nervous system to fulfill an as-yet-unidentified physiological need."

Upside-down jellyfish spend most of their time sitting on the seafloor with their stubby arms and tentacles sticking up from their gelatinous bodies, or bells. The animals pulse their bells to filter feed and get rid of waste (*SN: 9/6/14, p. 16*).

To qualify as sleeping beings, the jellyfish had to pass three tests. First, the jellyfish had to show they become less active at a particular time of day. By monitoring the pulsing of 23 upside-down jellyfish day and night for six days, the researchers discovered that the animals pulsed about 32 percent less at night. The team could easily reverse this sleepy state by dropping food into the tank. "The jellyfish immediately responded to the stimulus and started pulsing more," Nath says.

Second, the jellyfish had to be less responsive at certain times. "For people, that would be like if you're asleep, you are less likely to respond to someone talking to you," Abrams says. Since *Cassiopea* prefers to swim down to settle on a surface, the researchers hoisted up a jellyfish in a plastic pipe with mesh on the bottom, let the animal settle for five minutes and then quickly lowered the pipe. That action effectively placed the jellyfish free-floating into the water column. At night, the researchers found, it took the jellyfish longer to begin pulsing and reach the bottom of the tank than during the day.

Finally, the jellyfish had to show they need regular periods of sleep to survive. After being kept active for up to 12 hours overnight by squirts of water, the jellyfish were less active the following morning. That sluggishness was a sign that the jellyfish need to make up for the loss of rest, says study coauthor Claire Bedbrook.

"The authors do a good job of demonstrating that jellyfish fulfill the most fundamental criteria for sleep," Joiner says.

A big question for cnidarians, and most animals, is not only if they sleep, but why. Jellyfish sleep can hardly be compared with human sleep, Abrams says, but by studying the creatures, "we might be able to get at those core, fundamental components of why something sleeps." ■

CALTECH



See upside-down jellyfish in action at **bit.ly/SN_Cassiopea**

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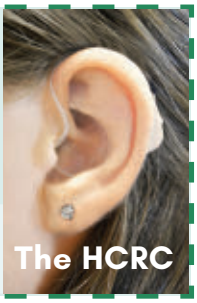


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LIFE & EVOLUTION

# Some herbivorous dinos ate critters

## Crustacean shells in fossilized poop reveal dietary secrets

**BY CAROLYN GRAMLING**

Some dinosaurs liked to cheat on their vegetarian diet.

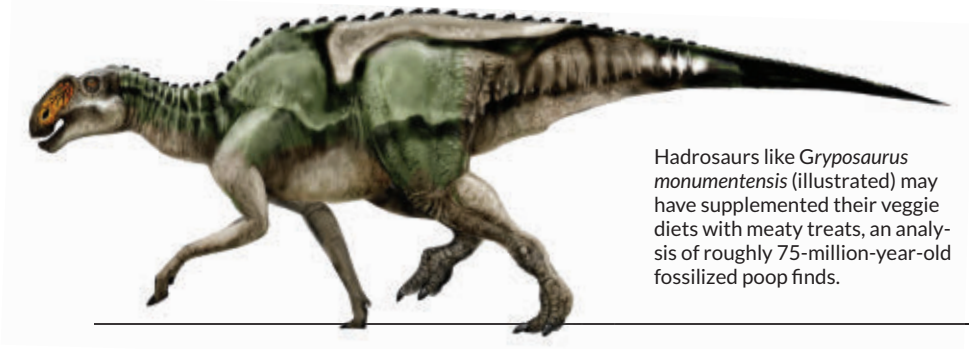
Based on the shape of their teeth and jaws, large plant-eating dinosaurs are generally thought to have been exclusively herbivorous. But for one group of dinosaurs, roughly 75-million-year-old poop tells another story. The fossilized droppings, or coprolites, contained tiny fragments of mollusk and other crustacean shells along with an abundance of rotten wood, researchers report September 21 in *Scientific Reports*. Eating the crustaceans as well as the wood might have given the dinosaurs an extra dose of nutrients during breeding season to help form eggs and nourish the embryos.

"Living herd animals do occasionally turn carnivore to fulfill a particular nutritional need," says vertebrate paleontologist Paul Barrett of the Natural History Museum in London. "Sheep and cows are known to eat carcasses or bone when they have a deficiency in a mineral such as phosphorus or calcium, or if they're pregnant or ill." But the discovery that some plant-eating dinos ate crustaceans is the first example of this behavior in an extinct herbivore, says Barrett, who was not involved in the new study.

Ten years ago, Karen Chin, a paleoecologist at the University of Colorado Boulder, described finding large pieces of rotted wood in dino dung. The coprolites were within a layer of rock in Montana, known as the Two Medicine Formation, dating to between 80 million and 74 million years ago. That layer also contained numerous fossils of *Maiasaura*, a type of large, herbivorous duck-billed dinosaur, or hadrosaur (*SN: 8/9/14, p. 20*).

Chin wondered whether the wood itself was the dino's dietary target. "The coprolites in Montana were associated with the nesting grounds of the *Maiasaura*," she says. "I suspected that the dinosaurs were after insects in the wood."

Supporting evidence now comes from an 860-meter-thick layer of rock in Utah known as the Kaiparowits Formation, which dates to between 76.1 million and 74 million years ago. Ten of the 15 coprolites that Chin's team examined contained tiny fragments of shell that were scattered throughout the dung. They were too small to identify by species, and



Hadrosaurs like *Gryposaurus monumentensis* (illustrated) may have supplemented their veggie diets with meaty treats, an analysis of roughly 75-million-year-old fossilized poop finds.

BODY & BRAIN

# Early body layout depends on brain

## Muscle, nerve growth goes haywire in brainless frogs

**BY LAURA SANDERS**

Frog brains get busy long before they're fully formed. Just a day after fertilization, embryonic brains begin sending signals to far-off places in the body, helping oversee the layout of complex patterns of muscles and nerve fibers. And when the brain is missing, bodily chaos ensues, scientists say September 25 in *Nature Communications*.

The results, from brainless embryos and tadpoles, broaden scientists' understanding of the types of signals involved in making sure bodies develop correctly, says Catherine McCusker, a developmental biologist at the University of Massachusetts Boston. Scientists are familiar with short-range signals among nearby cells that help pattern bodies. But these newly described missives traveling from the brain to the far reaches of the body are "the first example of really long-range signals," she says.

Celia Herrera-Rincon of Tufts University in Medford, Mass., and colleagues came up with a simple approach to tease out the brain's influence on the growing body. Just a day after fertilization, the scientists lopped off the still-forming brains of African clawed frog embryos. These embryos survive to become tadpoles even without brains, a quirk of biology that lets researchers see whether the brain is required for body development.

The answer was a definite yes, Herrera-Rincon says. Long before the brain is mature, it's already organizing and guiding organ behavior, she says. Brainless tadpoles had bungled patterns of muscles. Normally, muscle fibers form in a stacked chevron pattern. But in tadpoles lacking a brain, "the borders between segments are all wonky," says study coauthor Michael Levin, also of Tufts. "They can't keep a straight line."

Nerve fibers that crisscross tadpoles' bodies also grew in an abnormal pattern. Levin and colleagues noticed extra nerve fibers snaking across the brainless tadpoles in a chaotic pattern, "a nerve network that shouldn't be there," he says.

Muscle and nerve abnormalities are the most obvious differences. But brainless tadpoles probably have more subtle defects in other parts of their bodies, such as the heart. Ongoing experiments will search for those defects, Levin says.

In addition to keeping patterns on point, the young frog brain may protect its body from chemical assaults. A molecule that binds to certain proteins on

may have been crabs, insects or some other type of shelled animal, Chin says. Based on the scattering, the animals were certainly eaten along with the wood rather than arriving later to the feces.

Since bones from hadrosaurs are especially abundant in the Kaiparowits Formation, Chin suspects those kinds of dinos deposited the dung. Other large herbivores, such as three-horned ceratopsians and armored ankylosaurs, also roamed the area (*SN: 6/24/17, p. 4*).

The crustacean diet cheat may have been a seasonal event, related perhaps to breeding to obtain extra nutrients, Chin and colleagues say.

But how often — or why — the dinosaurs ate the shelled critters is hard to prove from the fossil dung alone, says Barrett. The preferential preservation of coprolites with hard crustacean bits instead of coprolites with soft leaves and other plant material might make it appear that this behavior was more frequent than it actually was. "These kinds of things give neat snapshots of specific behaviors that those animals are doing at any one time," he adds. "But it's difficult to build that into a bigger picture." ■

cells in the body had no effect on normal embryos. But when given to brainless embryos, the same molecule caused spinal cords and tails to grow crooked.

"The brain is instructing cells that are really a long way away from it," Levin says. While the precise identities of these long-range signals aren't known, the researchers have some ideas. When brainless embryos were dosed with a drug that targets cells that typically respond to the chemical messenger acetylcholine, the muscle pattern improved. Similarly, the addition of a protein called HCN2 that can tweak the activity of cells also seemed to improve muscle development.

Frog development isn't the same as mammalian development, but frog development "is pretty applicable to human biology," McCusker says. The results hint that a growing human brain might interact similarly with a growing human body. ■

MATH & TECHNOLOGY

# Origami outfits help bots retool

## Remote-controlled tiny cubes shift shapes when heated up

**BY MARIA TEMMING**

Robots are taking "dress for success" to a whole other level.

A new type of shape-shifting robot can undergo complete metamorphosis in a matter of minutes. The bot is composed of a simple metal cube that wraps itself in various high-tech origami sheets that fold into wings, wheels and other appendages for getting around. By donning and doffing different origami exoskeletons, the metal core can quickly switch from a walking to rolling to sailing bot and back again.

"It's almost like putting clothes on the robot to give it different kinds of powers," says study coauthor Daniela Rus, a roboticist at MIT. Such quickly customizable machines, described online September 27 in *Science Robotics*, could be useful for everything from surgery to space manufacturing.

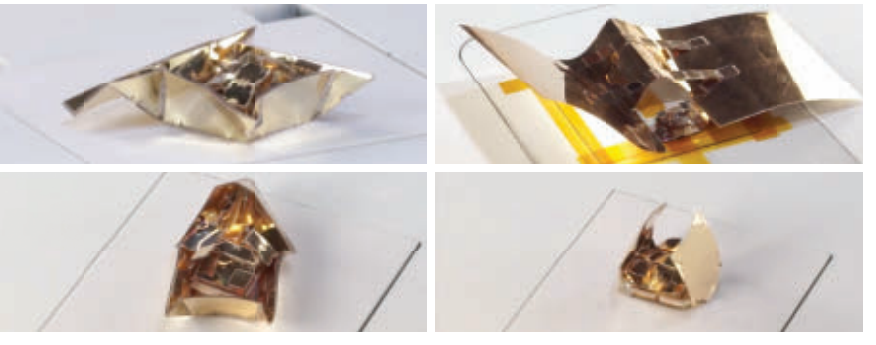
At the heart of each tiny transformer is a magnetic cube a few millimeters across, which Rus' team "drove" using magnetic coils of wire called solenoids as remote controls. To enclose this magnetic engine inside an origami body, the researchers parked the cube atop a flat origami sheet: a layer of heat-shrinking material (the same kind used to make Shrinky Dinks) sandwiched between two panes of polyester. Along the fold lines, the researchers had peeled away strips of polyester to expose the shrinking film.

When a heating pad underneath the origami sheet reached 65° Celsius, the heat-shrinking material along the creases contracted, causing the sheet to fold into a 3-D body, dubbed "Walk-bot," that allowed the bot to amble. Rus' team then used the same method to encompass the Walk-bot body inside other origami exoskeletons to create a bigger Walk-bot, Wheel-bot, Boat-bot or Glider-bot.

Once the robot was all suited up, Rus and colleagues used the solenoids to make it walk or roll, sail on water or glide through the air. The outer exoskeletons were fastened into place with four latches made of water-soluble material, allowing the Walk-bot to shuck its origami outerwear by getting these clasps wet. Then, leaving the used exoskeleton behind, Walk-bot could enfold itself in a new origami body. Future exoskeleton designs could arm robots with drills, scissors, shovels or grippers.

Such adaptable robots may be used for incision-free surgery, says Antoine Cully, a roboticist at Imperial College London who was not involved in the study. A patient could ingest a magnetic core and various exoskeletons, which a surgeon would then remotely control from outside the body.

Shape-shifting robots could also be useful in other situations where they must perform a wide range of tasks without packing lots of spare parts, like during emergency response operations in natural disasters or for space manufacturing. ■



MIT CSAIL

This small robot puts on different origami exoskeletons so it can (clockwise from top left) walk, glide, roll or sail. Such bots could someday aid in surgery, disaster response or space manufacturing.

Watch a robot change shape at **bit.ly/SN_origamirobots**

MATTER & ENERGY

# Quantum video chat links Asia, Europe

## Intercontinental call is step toward ultrasecure communications

**BY EMILY CONOVER**

Hackers, take notice: Ultrasecure quantum video chats are now possible across the globe.

In a demonstration of the world's first intercontinental quantum link, scientists held a long-distance videoconference on September 29 between Austria and China. To secure the communication, a Chinese satellite distributed a quantum key, a secret string of numbers used to encrypt the video transmission so that no one could eavesdrop. In the call, Chunli Bai, president of the Chinese Academy of Sciences in Beijing, spoke with Anton Zeilinger, president of the Austrian Academy of Sciences in Vienna.

"It's a huge achievement," says quantum physicist Thomas Jennewein of the University of Waterloo in Canada. "It's a major step to show that this approach could be viable."

Quantum key distribution lets users share secret strings of numbers while ensuring that no eavesdroppers can intercept the code undetected. Those quantum keys are then used to encrypt information sent via traditional internet connections. Decoding the transmission requires the same key.

China's Micius satellite, which launched in 2016, uses lasers to beam photons, or light particles, to ground stations on Earth. Micius sent a series of photons encoding a string of 0s and 1s to a ground station near Vienna. The satellite stored information about the sequence until it reached a station near Beijing, where Micius beamed down another string of photons. Then the satellite combined the two sets of numbers and relayed additional info to the stations to let them create matching keys.

Scientists have used Micius to distribute quantum keys between the satellite and the ground, teleport the properties of photons from the ground into space, and produce photons with their properties linked, or entangled, despite being separated by 1,200 kilometers (*SN: 8/5/17, p. 14*). The video chat is the first time researchers have exchanged quantum keys between different continents.

The chat was not completely secure, but it was about a million times as secure as what's possible with standard encryption, says Rupert Ursin, a physicist at the Institute for Quantum Optics and Quantum Information in Vienna and a member of the Austrian team. The teams also exchanged images using theoretically uncrackable methods. ■

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LIFE & EVOLUTION

# Hermit crab takes shelter in corals

## Species' flexible symbiotic relationship surprises experts

A newly discovered hermit crab (one shown returning upright after a fall) is the first known to use mobile corals as a covering.

M. IGAWA AND M. KATO/*PLOS ONE* 2017

**BY MARIAH QUINTANILLA**

A hermit crab species discovered in southern Japan has been enjoying the perks of living like a peanut worm. Like the worms, the 7- to 8-millimeter-long crabs use corals as coverings, researchers report September 20 in *PLOS ONE*.

Other kinds of hermit crabs typically move in and out of a series of mollusk shells as the crabs grow. *Diogenes heteropsammicola* is the first known to form a mutually beneficial relationship with "walking" corals. These corals aren't attached to the seafloor. Instead, each coral grows with and around a crab, forming a cavity in the coral skeleton that gives a permanent home for the crab. In exchange, the crab helps the coral "walk."

Walking corals were already known to be in symbiotic relationships with marine peanut worms. A symbiotic shift between such distantly related species as the worms and the crab is rare because organisms in a mutualistic relationship tend to be specialized and completely dependent on one another, says study coauthor Momoko Igawa, an ecologist at Kyoto University in Japan.

But *D. heteropsammicola* appears to be well-adapted to live in the corals. Its extra slim body fits inside a coral's narrow cavity. And unlike other hermit crabs — whose tails curve to the right to slip into spiral shells — *D. heteropsammicola*'s tail tip is symmetrical and can curl either way, just like a coral's opening.

"Being able to walk around in something that is going to grow larger as you grow larger, that's a big plus," says Jan Pechenik, a biologist at Tufts University in Medford, Mass. A typical hermit crab that can't find a larger shell to move into "really is in trouble."

Igawa suspects *D. heteropsammicola*'s relationship with walking corals begins when a walking coral larva latches onto a tiny mollusk shell containing a juvenile hermit crab and starts to grow. When the crab outgrows the shell, the crustacean moves into the more spacious host coral's crevice, and the shell remains encapsulated in the coral.

By observing the hermit crab in an aquarium, Igawa and Makoto Kato, also an ecologist at Kyoto, determined crabs provide corals with the same services as worms: transportation and protection. ■

# Spacecraft finds no rings around Pluto

## Lack of debris may mean safe travels for New Horizons probe

**BY LISA GROSSMAN**

Pluto has no rings — New Horizons triple-checked. An exhaustive search for rings and dust particles around the dwarf planet before, during and after the spacecraft flew past Pluto in 2015 has come up empty.

"It's a very long paper to say we didn't find anything," team member Tod Lauer says of the analysis, posted September 23 at arXiv.org. But the nonresult could help scientists understand the contents of the outer solar system and help plan New Horizons' next encounter. The spacecraft is now on a course to a space rock in the Kuiper Belt, about another 1.5 billion kilometers past Pluto.

Before New Horizons arrived at Pluto, the possible existence of rings was an urgent matter of safety. Hitting a particle as small as a sand grain could have damaged the spacecraft.

Searches with the Hubble Space Telescope in 2011 and 2012 turned up two previously unknown moons orbiting Pluto — Kerberos and Styx (*SN: 11/28/15, p. 14*) — and zero rings. Even so, many researchers expected to encounter rings, or at least some debris. The four outer planets in the solar system have rings, as do other small bodies in the solar system, such as the tiny planetoid 10199 Chariklo (*SN: 5/3/14, p. 10*). And some studies suggest that Pluto probably had rings at some point in its past, left over from the collision that formed its largest moon, Charon.

Nine weeks before New Horizons' closest approach to Pluto, a team jokingly named the "crow's nest" acted much like a ship's lookout for potential hazards, says Lauer, an astronomer with the National Optical Astronomy Observatory in Tucson. The group examined images taken with the spacecraft's Long Range Reconnaissance Imager camera, looking for ring particles reflecting sunlight or spots that moved against a starry background from one set of images to the next. Nothing unusual turned up.

> "It's a very long paper to say we didn't find anything."
>
> **TOD LAUER**

The team declared the spacecraft's trajectory safe, and New Horizons sailed safely past Pluto on July 14, 2015 (*SN Online: 7/15/15*). After the flyby, the team turned New Horizons around to look back at Pluto, and toward the sun. This was a much better position to look for rings, as dust particles would pop into view when backlit by the sun like motes of dust in the light from a window.

"If you really want to know for sure whether there's any dust there, the viewing geometries where you're looking past the dust with the sun in the background, that's the gold standard," says Matthew Tiscareno of the SETI Institute in Mountain View, Calif., who studied Saturn's rings with the Cassini spacecraft.

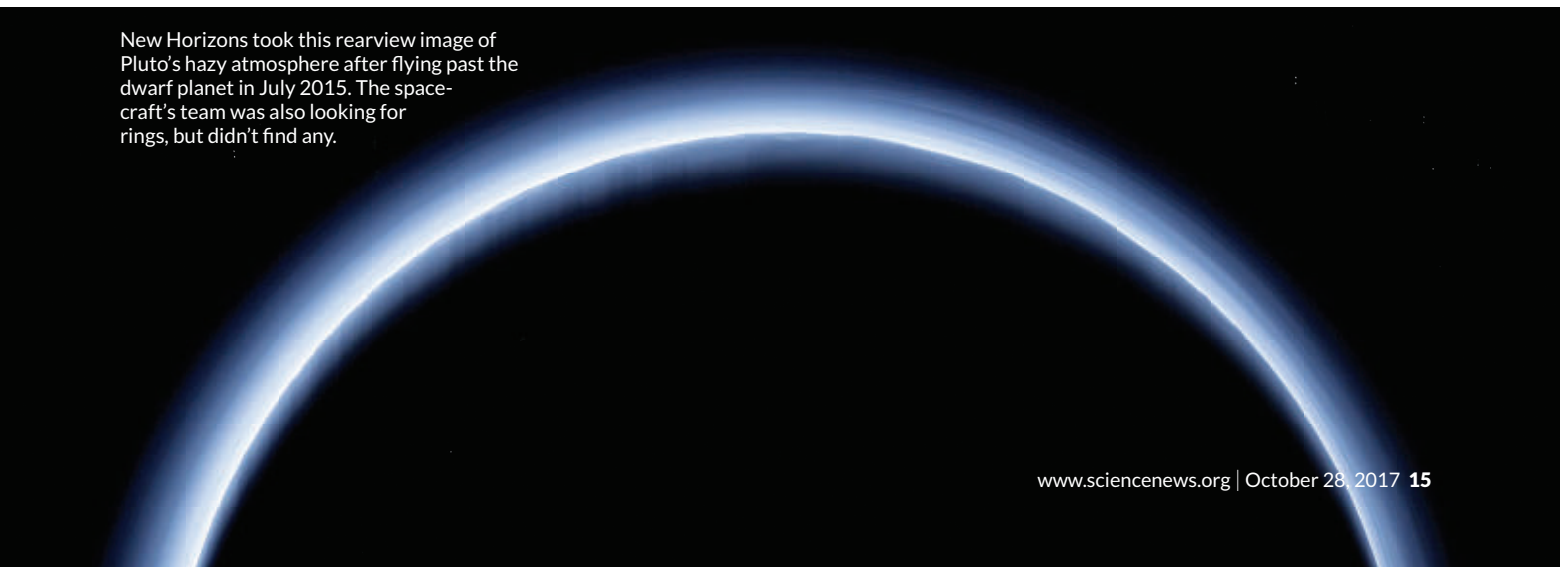
It took the better part of a year for all the flyby data to return to Earth, and several months for scientists to analyze that data, but the team is now ready to call it: The rings really aren't there — or at least they're too diffuse to see.

That's somewhat surprising, Lauer says. But the chaotic gravitational pulls of Pluto's family of moons might make it too hard for rings to find stable orbits. Or the slight pressure generated by light particles streaming from the sun could constantly blow would-be ring particles away.

It's also possible there just wasn't that much dust there to begin with. New Horizons saw fewer craters on Pluto and Charon than expected, which could mean there are fewer small bodies at that distance from the sun smacking into Pluto and its moons and kicking up dust.

That could be good news for New Horizons' next act. After five months in hibernation, the spacecraft woke up on September 11 and set its sights on a smaller, weirder and more distant object: a space rock about 30 kilometers long called 2014 MU69. Initial observations suggest it's a double object, with two bodies orbiting closely or lightly touching.

New Horizons will fly past MU69 on January 1, 2019. In the meantime, the team is looking for hazards along the route. "We're going to do a similar effort to what we did with Pluto," Lauer says. "We're going to get in the crow's nest and get out our binoculars, as it were, and see if we're going to be OK." ■



SWRI, JHUAPL, NASA

New Horizons took this rearview image of Pluto's hazy atmosphere after flying past the dwarf planet in July 2015. The spacecraft's team was also looking for rings, but didn't find any.

LIFE & EVOLUTION

# Neonicotinoids found in honey globally

## Bee-harming pesticides show up in 75 percent of study samples

**BY LAUREL HAMERS**

Neonicotinoid pesticides are turning up in honey on every continent with honeybees.

The first global honey survey testing for these controversial pesticides shows just how widely honeybees are exposed to the chemicals, which are chemically similar to nicotine and have been shown to harm bees and other insects. Three out of four honey samples tested contained measurable levels of at least one of five common neonicotinoids, researchers report in the Oct. 6 *Science*.

"On the global scale, the contamination is really striking," says study coauthor Edward Mitchell, a soil biologist at the University of Neuchâtel in Switzerland. The pesticides are used on many kinds of crops grown in different climates, but traces of the chemicals showed up even in honey from remote islands with very little agriculture.

"I used to think of neonicotinoids as being a [local] problem next to a small set of crops," says Amro Zayed, who studies bees at York University in Toronto and wasn't involved in the research. These pesticides "are much more prevalent than I previously thought."

Mitchell's team collected 198 honey samples from around the world. The presence of pesticides varied regionally. Of the North American samples, 86 percent contained at least one of the five neonicotinoids that the study measured, while only 57 percent of South American ones did. Almost half of all samples globally contained more than one type of the pesticides, evidence that bees were often foraging in multiple sites affected by pesticides. In all the samples, pesticide levels were below what has been established as safe for human consumption.

Neonicotinoids gained popularity as pesticides in the 1990s in part because they target the central nervous system of crop-destroying insects but don't have the same effects in humans. But the pesticides have been controversial, because studies have found that they can hurt pollinators as well as pests (*SN: 5/16/15, p. 13*). There has been dispute over whether the pesticides are a major contributor to pollinator decline, with some farmers and pesticide manufacturers arguing that habitat loss and parasite infection have a bigger impact on bee populations. This new research documents widespread exposure of honeybees to neonicotinoids at levels that have been shown to harm insect health in previous studies, Mitchell argues.

Most concerns about bees have centered on the European honeybee (*Apis mellifera*), which people have spread around the world as a crop pollinator. But native pollinators can be exposed to neonicotinoids, too, and are often more vulnerable to the pesticides' effects, says Geraldine Wright, an insect neuroethologist at Newcastle University in England. Bumblebees and sweat bees tend to live in smaller hives than honeybees, so just a few foragers can more quickly spread contamination to the whole colony. ■

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NEWS IN BRIEF

HUMANS & SOCIETY

### DNA pushes back human origins

A boy who lived in southern Africa nearly 2,000 years ago has lent a helping genome to science. Using the boy's DNA, scientists have estimated that humans emerged as a distinct population between 350,000 and 260,000 years ago, earlier than thought.

The trick was retrieving a complete version of the boy's DNA from his skeleton to compare with DNA from people today and from Stone Age Neandertals and Denisovans. Previously documented migrations of West African farmers to East Africa about 2,000 years ago, and then to southern Africa about 1,500 years ago, reshaped Africans' genetics — and obscured ancient ancestry patterns — more than has been known, researchers report online September 28 in *Science*.

The boy's DNA was not affected by those migrations. So it provides the best benchmark so far for gauging when *Homo sapiens* originated, evolutionary geneticist Carina Schlebusch of Uppsala University in Sweden and colleagues say.

In line with the new work, another team has proposed that 300,000-year-old fossils from Morocco are of *H. sapiens* (*SN: 7/8/17, p. 6*). But scientists often place our species' origins closer to 200,000 years ago. There's broad consensus that fossils from that time represent *H. sapiens*.

Debate over the timing of human origins will continue, says study coauthor Mattias Jakobsson, also of Uppsala. Researchers have yet to retrieve DNA from potential *H. sapiens* fossils dating from 200,000 to 300,000 ago. — *Bruce Bower*

LIFE & EVOLUTION

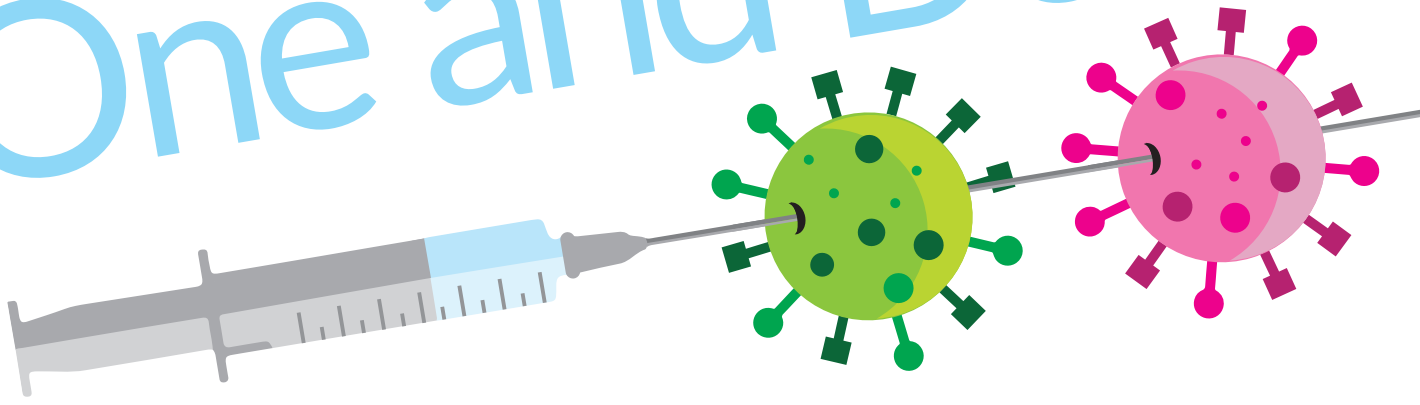
### Baby ichthyosaur ate cephalopod

As far as last meals go, squid isn't a bad choice. Remains of a squidlike cephalopod appear to dominate the stomach contents of an almost 200-million-year-old ichthyosaur fossil.

Ichthyosaur bones commonly pop up on England's fossil-rich coast near Lyme Regis. But a lot of museum specimens lack records, making their age difficult to place. Dean Lomax of the University of Manchester in England and colleagues reexamined one such fossil, the researchers report online October 3 in *Historical Biology*. Based on its skull, they identified the creature as a newborn *Ichthyosaurus communis*. Microfossils of shrimp and amoebas around the marine reptile put the specimen at 199 million to 196 million years old.

Hook structures stand out in the baby's ribs — probably the remnants of arms from an ancient squid relative. Fish were the food of choice for the young of another type of ichthyosaur that lived more recently, previous research has suggested. — *Helen Thompson*

# One and Done



## A universal flu vaccine might be nearing reality

**By Laura Beil**

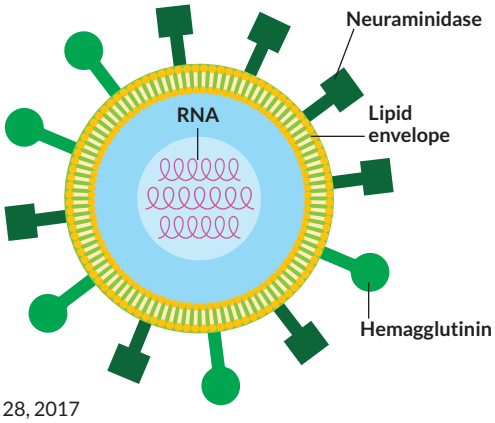
One of the planet's deadliest viruses makes an annual pass through the United States with little fanfare. It rarely generates flashy headlines or news footage of health workers in hazmat suits. There's no sudden panic when a sick person shows up coughing and feverish in an emergency room. Yet before next spring, this season's lethal germ will probably have infected millions of Americans, killing tens of thousands. Still, it's often referred to as *just* the flu.

The influenza virus seems so normal to most Americans that only about half of us will heed those "time for your flu shot" banners that pop up at pharmacies and worksites every autumn. Those annual shots remain the best means of protection, but they must be manufactured months before flu season starts, based on a best educated guess of what strains of the virus will be circulating. That means even in a successful year, vaccine performance may not be impressive. During the 2015–2016 season, only about half of those immunized were protected, according to a study in the Aug. 10 *New England Journal of Medicine*. Some years' vaccines are duds: For the 2014–2015 season, the vaccine protected only 19 percent of people who received it, based on U.S. Centers for Disease Control and Prevention data.

Scientists have long worked to develop a flu shot that works better and lasts longer. But, unlike the very stable measles virus, influenza is a moving target. While only a few strains of flu virus circulate worldwide in a typical year, dozens more may exist. Each one is highly likely to mutate from year to year, with just enough shape-shifting to be unrecognizable to the body's defenses.

Now, after years of searching, scientists believe they have better strategies to attack the parts of the virus that stay the same from year to year, offering the hope of protection across multiple seasons. The vaccines being developed in laboratories around the world "offer more promise than we've ever had," says Walter Orenstein, associate director of the Emory Vaccine Center in Atlanta. And there are new creative approaches: One research group is trying to make a kind of super shot by anticipating every possible mutation a circulating virus might undergo.

"I'm optimistic we are going to get to a vaccine," says Anthony Fauci, head of the National Institute of Allergy and Infectious Diseases, or NIAID, in Bethesda, Md. Then, you may need to heed those "time for your flu shot" messages only once.

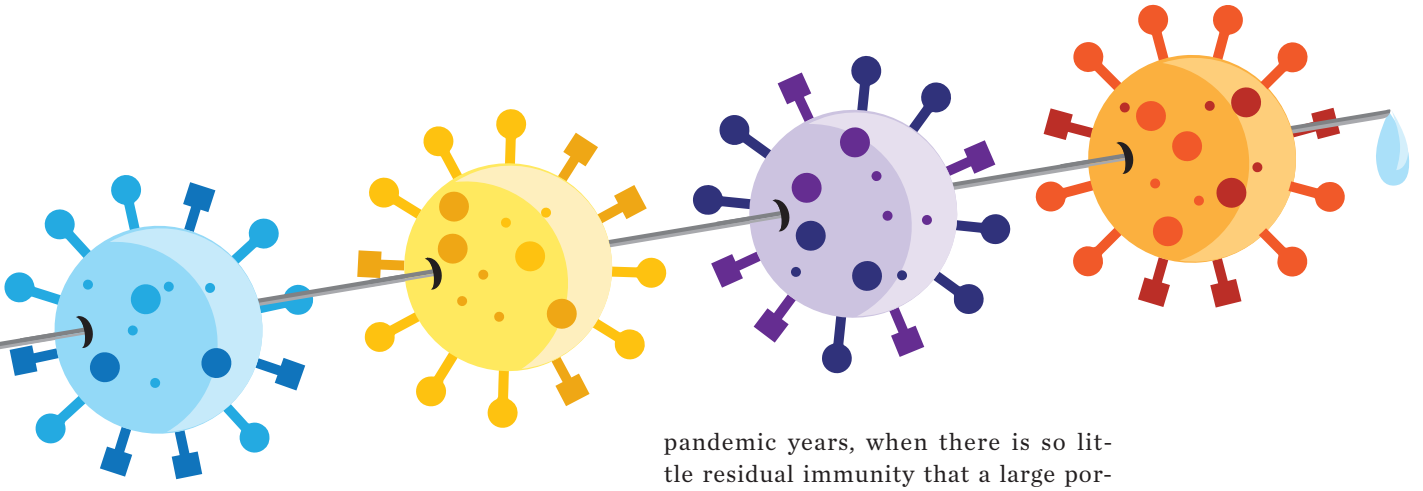



**Evasive maneuvers**
The proteins hemagglutinin and neuraminidase sit on the surface of the flu virus. From year to year, those proteins usually undergo just enough change to evade the immune system.

### Stalking a killer

Researchers often describe the flu virus as looking like a ball with lollipops sticking out. Tucked

E. OTWELL



inside the ball is RNA, which the virus needs to make copies of itself. The lollipops on the outside are proteins: hemagglutinin and neuraminidase. There are 18 different kinds of hemagglutinin and 11 kinds of neuraminidase. Each kind of flu virus is named for its particular combination of these proteins; the current forms circulating around the world are H1N1 and H3N2. Hemagglutinin attaches to human cells to launch an infection; neuraminidase is more important for spreading the virus once infection has occurred.

Flu viruses involved in human epidemics are divided into types A and B, and A viruses are sliced even further into group 1 and group 2. Influenza A, the most troublesome for vaccine scientists, travels the world among birds, pigs and humans. The bird and pig versions don't easily infect people, but the virus is constantly mutating and even swapping genes with other influenza viruses it meets along the way. Sometimes these genetic changes create a version that allows a bird or pig flu to move directly into humans. In 2013, one called H7N9 moved into people in China (*SN Online: 3/11/15*). The virus has since infected more than 1,500 people. Mostly, though, the genetic changes are more subtle, with just enough alterations to evade the human immune system.

Like kids with a sweet tooth, the immune system gets most excited about the top part of the hemagglutinin lollipop, and makes antibodies against it. The top is, after all, the first thing the immune system notices once the virus slips inside the nose, mouth and lungs. Every year, genetic mutations in the virus slightly change the chemical flavor of the lollipop, making it more sweet or sour than last season's — just different enough so the immune system doesn't recognize it. That's why most years there's a new flu shot.

Sometimes, in the gene shuffling with viruses in birds and pigs, the changes are so great that the flavor changes completely. Those are pandemic years, when there is so little residual immunity that a large portion of the global population falls ill from the new virus. The devastating 1918 flu, which killed an estimated 50 million people globally, was caused by such a drastic genetic shift (*SN Online: 4/29/14*). The most recent pandemic occurred in 2009, with the appearance of the "swine flu," so named because the virus was first found in pigs. By one analysis, it caused between 148,000 and 249,000 deaths around the world.

## Attack the stem

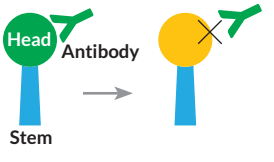
The 2009 disaster helped provide a blueprint for some of the latest experimental vaccines. Researchers noticed that when people with swine flu developed antibodies to the virus, those antibodies did something odd: They favored the hemagglutinin stem — the stick of the lollipop. And, more important, they appeared to react broadly against two kinds of flu virus. Scientists had known that the hemagglutinin stem, or stalk, isn't as apt to change as the lollipop top, which theoretically makes the stem a good target for a universal vaccine. But in a usual flu season, the human body isn't inclined to make infection-fighting antibodies against the stem.

"Unfortunately, the immune system preferentially recognizes the head, and we don't know why it does that," says Adrian McDermott, an immunologist at NIAID. So after infection, the biggest share of antibodies flocks to the hemagglutinin head. (Neuraminidase, the bigger player in disease after infection, is a target for influenza treatments but not a major focus for vaccine development.)

But in a study reported in the *Journal of Experimental Medicine* in 2011, a team of scientists from Emory and elsewhere found that antibodies to the so-called

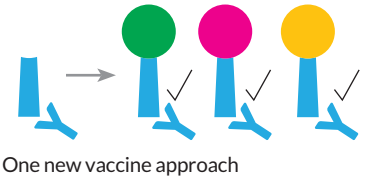
**A new target** Teams are developing flu vaccines that prompt the body to respond to the stem of the hemagglutinin protein. The stem is a more stable target than the protein head. SOURCE: F. KRAMMER/ *CURRENT OPINION IN VIROLOGY* 2016

**Traditional approach**




Most traditional vaccines generate antibodies against the hemagglutinin head. If the head changes, the vaccine no longer works.

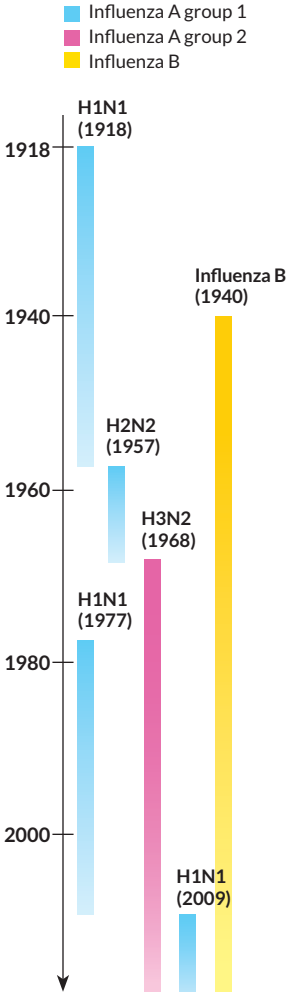
**"Headless" approach**



One new vaccine approach prompts the body to make antibodies to the more stable stem. If the head changes, the vaccine still works.

E. OTWELL

**Shifting strains**
While the most widely circulating flu viruses mutate slightly from year to year, sometimes they undergo major changes. The current types of flu circulating are H3N2 and H1N1, named after the configuration of hemagglutinin and neuraminidase.




SOURCE: R. NACHBAGAUER AND F. KRAMMER/*CLINICAL MICROBIOLOGY AND INFECTION* 2017

swine flu behaved unexpectedly. "If you have a head that the immune system hasn't seen, you potentially redirect to a stalk response," McDermott says. "That was an aha! moment."

Researchers investigated further. For one study in 2012 in *Frontiers in Immunology*, scientists from Canada injected these stem-recognizing antibodies into mice to see if the mice were shielded from a different strain of flu. Not only were the mice protected from lethal doses of flu virus, but the protection was also in large part due to the absence of familiar antibodies against the head, the researchers found. Without the distraction of a head it recognized, the immune system seemed to rally against the stem.

Then came the what ifs: What if a vaccine produced just antibodies to the stem? Would that be enough protection? For the last few years, McDermott and others have been trying to develop vaccines made of "headless stalks" — just the sticks of the lollipops. With no head in place to hoard the immune response, the vaccine might coax the body to make enough stem-focused antibodies to protect against flu, the researchers hoped, regardless of the seasonal mutations occurring at the top.

Several groups soon found that headless stalks are difficult to make. Without the top to stabilize it, the molecular assembly tended to break apart. Two teams working independently reported in 2015 their success in keeping the stalk in one piece. NIAID scientists and their partners held the stalks together by anchoring them to the protein ferritin, which can assemble itself into nanoparticles. In a study in *Nature Medicine*, the team reported that vaccinated mice and ferrets appeared to be protected from dying of the H5N1 bird flu after receiving the vaccine, even when they developed symptoms. Unvaccinated mice and ferrets died.

The second team, from the Janssen Center of Excellence for Immunoprophylaxis in Leiden, the Netherlands, and the Scripps Research Institute in La Jolla, Calif., glued the stalk together by creating a series of genetic mutations at its top. In *Science*, the researchers reported that the vaccine reduced the symptoms of flu in vaccinated monkeys.

"We realized that the stem has much less variability than the head, and then we developed the capability to use it for a possible vaccine," says Fauci, commenting on both efforts. "These were two important things that came together."

Despite progress, these stalk-focused vaccines haven't yet been put to human tests that would show whether they could protect broadly against many mutations of flu circulating annually, which is the ultimate test. And some stalk-directed antibodies might be better than others. In July in *Science Immunology*, McDermott and colleagues reported that the stalk antibodies against group 2 of the A viruses appear to be more broadly effective than those against group 1 viruses.

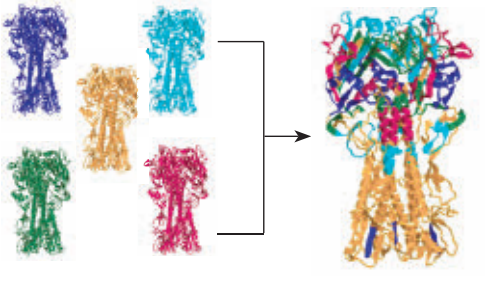
Other researchers have stabilized the stalk by attaching a new hemagglutinin head — a lollipop flavor that the human immune system has never tasted. In this case, researchers from the Icahn School of Medicine at Mount Sinai in New York City took tops from two flu strains that circulate only in birds, and connected each one to a human hemagglutinin stalk. This experimental vaccine consists of two doses. The first dose prompts the immune system to make antibodies against the stalk with the first top, and a second dose produces a second round of antibodies against the stalk with the second top. The idea is that the abundance of stem-focused antibodies — amplified from the two shots of vaccine — will come to the rescue during a natural infection from a virus that possesses a third, totally different head.

"The human immune system will try to find something it has seen before," says Peter Palese, chairman of microbiology at Mount Sinai. In theory, the only antibodies in play will be the ones responding to the parts of the stalk that the immune system recognizes, known as the "conserved domains."

"The $64,000 question," according to Palese: "Will the immune response to these conserved domains be enough to elicit a broad immune system reaction?"

In 2016, Palese and colleagues described a test of the vaccine in the *Journal of Virology*. Six ferrets given the two doses were housed with six ferrets infected with H1N1 flu. Within 10 days, the vaccinated animals had become infected but had no

**Mix it up** One approach for a universal vaccine is to configure a molecule that contains almost all known mutations of hemagglutinin. The simplified cartoon below represents five hemagglutinin protein sequences mixed together into one. A computer program can generate thousands more possibilities to produce a single molecule.



T. ROSS/UNIV. OF GEORGIA

symptoms or signs of being able to easily spread virus to others. A report in June in the same journal described tests of the vaccine in mice against influenza B viruses; the animals were protected from normally lethal doses of flu.

What's not known is whether the stem-focused antibodies are enough to protect people from all virus variants. The vaccine from the Mount Sinai researchers is entering the first human safety trials with drugmaker GlaxoSmithKline.

## Unhide and seek

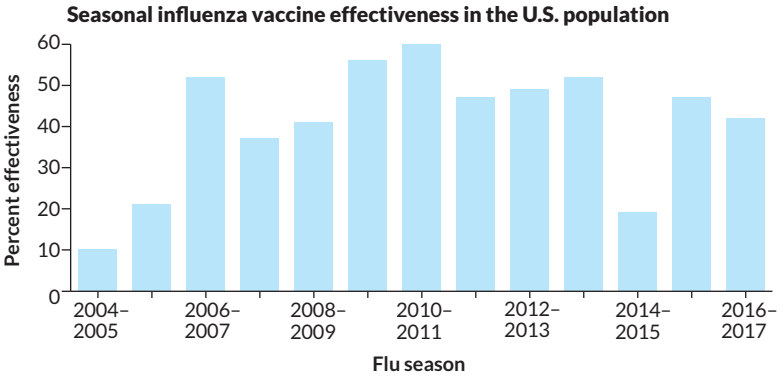
Another approach incorporates proteins that don't tend to mutate like the hemagglutinin head but are hidden from the immune system under normal circumstances. When these proteins are made visible to types of white blood cells called T cells, the immune system wakes up. T cells don't make antibodies, but certain T cells hold on to a memory of foreign molecules seen before. When these preprogrammed T cells recognize an infection, they destroy the invader.

This work began in the 1990s, when researchers at the Weizmann Institute of Science in Rehovot, Israel, set out to find parts of the virus that remain unchanged from year to year. The team identified stable regions in three proteins — hemagglutinin, plus one from the virus membrane and one from the virus core. In 2003, a company called BiondVax Pharmaceuticals formed to develop and test, in humans, an experimental vaccine that takes these proteins and packages them in a way that the immune system can recognize them.

So far, almost 700 volunteers have participated in six small trials, all of which showed signs of a lasting immune response among most volunteers. Writing in February in *Vaccine*, the researchers reported that the stored serum of elderly volunteers who received the vaccine in 2011 showed an immune response to new strains of flu that were circulating three years later. The company is starting larger trials to see if the vaccine can actually protect people from getting sick.

## Out of many, one

Other experimental vaccines take a different approach. Rather than relying on precision to hit a narrow target, microbiologist Ted Ross and colleagues at the University of Georgia in Athens are attempting to cast a wide net. The researchers are taking hemagglutinin mutations from every flu strain that has ever circulated, dumping them into a kind of scientific blender and attaching them to particles that can form the basis of a vaccine.




**Good years and bad** Vaccine makers must anticipate months in advance which strains of flu will circulate each year. Some seasons, such as in 2014–2015, effectiveness is low: A high percentage of people who get the shot still get the flu. SOURCE: CDC

"The question we asked is, how can we make a vaccine against a strain we don't even know exists?" Ross says. The technique he uses is called COBRA for computationally optimized broadly reactive antigen. A computer compiles all seemingly possible genetic iterations of a particular flu type — in this case H1N1 — and then bundles them into one molecule. It's kind of like taking every novel in your local library and combining them into one giant book.

Last year in the *Journal of Virology*, Ross and colleagues described a COBRA-derived vaccine that represented almost all forms of H1N1 that have been around for the last 100 years. The vaccine protected mice against infection from strains of H1N1 that the mice had never been exposed to. "We took a bunch of different hemagglutinins and mixed them into one hemagglutinin molecule," Ross says. "It protected against any strain of H1N1 we could throw at it."

The study caught the attention of vaccine maker Sanofi Pasteur, which plans to test the vaccine in clinical trials. Ross' lab is now using the same strategy to develop a vaccine against H3N2 strains, the other dominant kind of flu circulating around the world. Same approach, different library.

Meanwhile, the virus isn't waiting around. Based on the heavy flu season in the Southern Hemisphere, some experts are predicting this year's epidemic could be severe. It's still too early to know whether the current vaccine will provide good protection, but someday, a super shot may remove the guesswork altogether. ■

## Explore more


- Kaori Sano *et al*. "The road to a more effective influenza vaccine: Up to date studies and future prospects." *Vaccine*. September 25, 2017.


E. OTWELL

# real vampires of planet earth

Even scarier than the blood-sucking sea lamprey's teeth are the secretions that keep a victim's blood from clotting.

T. LAWRENCE, GLFC

## It's not easy sucking blood

**By Susan Milius**

Jennifer Zaspel can't explain why she stuck her thumb in the vial with the moth. Just an after-dark, out-in-the-woods zing of curiosity.

She was catching moths on a July night in the Russian Far East and had just eased a *Calyptra*, with brownish forewings like a dried leaf, into a plastic collecting vial. Of the 17 or so largely tropical *Calyptra* species, eight were known vampires. Males will vary their fruit diet on occasion by driving their hardened, fruit-piercing mouthparts into mammals, such as cattle, tapirs and even elephants and humans, for a drink of fresh blood.

Zaspel, however, thought she was outside the territory where she might encounter a vampire species. She had caught *C. thalictri*, widely known from Switzerland and France eastward into Japan as a strict fruitarian.

Before capping the vial with the moth, "I just for no good reason stuck my thumb in there to see what it would do," Zaspel says. "It pierced my thumb and started feeding on me."

Make that eight-plus vampires. Zaspel, an entomologist now at the Milwaukee Public Museum, is still puzzling over the genetics of the moths at the two Russian field sites she visited in 2006. Males there will bite a researcher's thumb if offered, yet genetic testing so far shows the moths are part of a vast, otherwise mild-mannered species.

Which is just as well. As vampires go, these moths are not stealth biters. "I would compare it to a bee sting," Zaspel says. For the sake of moth science, one of Zaspel's colleagues voluntarily documented the experience, noting that a moth will feed as long as 20 minutes. Such moth bites definitely get noticed. For these moths and other real-life vampires, being smacked to a smear is a bigger danger than getting staked through the heart.

Nabbing the occasional red lunch, or managing to survive on nothing but blood, is far more difficult than it looks in the movies. The relatively few animals that manage the lifestyle are indeed remarkable: some insects and other arthropods, a few mollusks, some fishes, birds on occasion and, of course, three kinds of bats.

Blood is not an easy food. There are pressures to gorge

as much as possible at each meal. At these heroic volumes, however, blood can be outright toxic. At the same time, a blood meal is insufficient, missing some basic nutrients. Surviving this way takes guts as well as other specialized physiology. Modern tools of genetics and molecular biology are revealing the hidden specializations required for blood feeding and helping make sense of lifestyles that go to different extremes, even mouth-to-mouth blood donation. Though many of these biological adaptations would never fit among the showy strengths of the immortals of *Twilight* or *True Blood*, they could certainly count as superpowers.

## Big dinner

To grasp the risks real vampires take, imagine an animal 35 million times your weight. Now bite it hard enough to make it bleed.

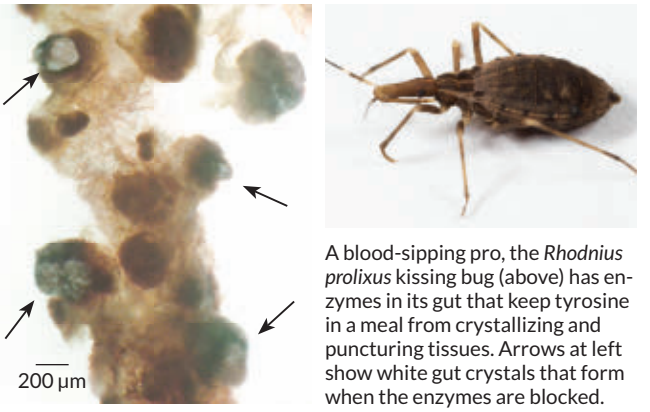
And make it mad. "You can easily get killed by the host," says insect molecular physiologist Pedro L. Oliveira of the Federal University of Rio de Janeiro. The 35 million multiplier applies for a 2-milligram female mosquito attacking a 70-kilogram human, measurements from an article he coauthored on nutritional overload in bloodsuckers in the August *Trends in Parasitology*.

Finding that giant blood source isn't easy. "If you go into a forest, you have hundreds of meters separating one vertebrate host from another, and hundreds of meters would be several kilometers for us," Oliveira says. Then the tiny vampire has to find a capillary for biting within just a few millimeters of the skin surface. On a human victim, Oliveira estimates, only about 10 percent of the skin acreage will do.

To grasp the risks real vampires take, imagine an animal 35 million times your weight. Now bite it hard enough to make it bleed.

Considering the dangers and difficulties that blood feeders face, "most of these guys try to minimize the number of visits," Oliveira says. They drink fast, and they drink big. A young kissing bug, with its deceptively friendly nickname and the ability to spread debilitating and possibly fatal Chagas disease, needs only minutes to down about 10 times its weight in blood.

To relate this to human physiology — forget it. There are people who intentionally drink blood, which is another story, but even small amounts in vampire terms, such as the amount of swallowed blood from a long nosebleed, can give a human diarrhea, says Tomas Ganz of the David Geffen School of Medicine at the University of California, Los Angeles. Fresh blood is difficult for the human gut to process, and too little of the water in blood gets extracted and routed to the kidneys. For its water-content challenges, Ganz compares fresh blood to the solutions people drink to clear their intestines, swiftly and unpleasantly, for a colonoscopy.



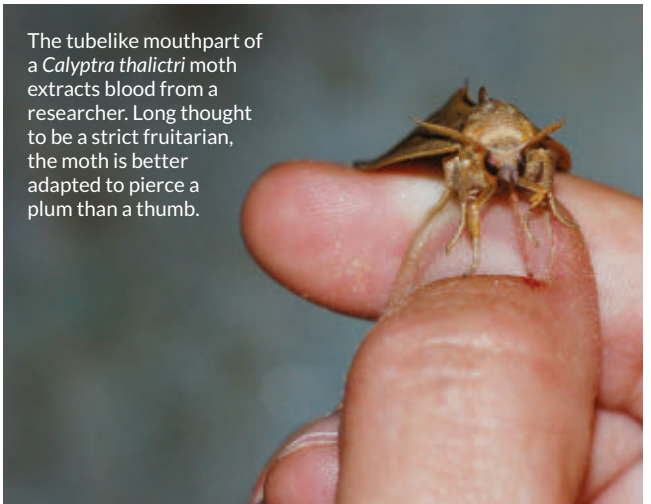

A blood-sipping pro, the *Rhodnius prolixus* kissing bug (above) has enzymes in its gut that keep tyrosine in a meal from crystallizing and puncturing tissues. Arrows at left show white gut crystals that form when the enzymes are blocked.

With such big blood meals, ingredients that would be harmless or healthful in small amounts can be toxic. "The dose makes the poison," Oliveira says.

Remove the water in blood, and what's left is almost 90 percent protein. Oliveira got an inkling of something perilous in that protein when his lab was exploring the genetics of one of the Americas' kissing bugs, *Rhodnius prolixus*. With a rounded rear that stretches and narrows at the head like a railroad-track penny that almost escaped, the bug lurks in crevices indoors or out. At night both males and females search out humans, their pets or other vertebrates pulsing with a good blood dinner. The bug has vampire superstealth and outdoes the vampire moths by biting without waking a sleeping blood source. Unlike mosquitoes and ticks whose bites deliver pathogens in saliva, a kissing bug delivers the Chagas disease parasite through its excrement, which the bug leaves on the host.

Of all the amino acids detected in that huge drink, only tyrosine meets a massive special array of enzymes ready to break it down as it washes into the kissing bug gut, researchers showed in 2014. Finding tyrosine-busting enzymes in the gut is "kind of strange," Oliveira says. In mammals, the liver and kidneys are the only organs with enzymes that break down tyrosine. Then again, most mammals don't flood their guts with overwhelming protein.

When researchers messed with the kissing bug to sabotage tyrosine breakdown, either by disabling genes or chemically blocking the enzymes, the bugs died after dining, Oliveira and colleagues reported in *Current Biology* in 2016. Some of the dead bugs had crystals of tyrosine stabbing through the



The tubelike mouthpart of a *Calyptra thalictri* moth extracts blood from a researcher. Long thought to be a strict fruitarian, the moth is better adapted to pierce a plum than a thumb.

CLOCKWISE FROM TOP LEFT: M. STERKEL *ET AL*/*CURRENT BIOLOGY* 2016; RAY WILSON/ALAMY; J. ZASPEL

gut lining, and gut contents had leaked into the body cavity. This discovery, researchers propose, might someday give molecular biologists their own drug to serve as a vampire-killing stake.

Blood feeding in arthropods has evolved independently multiple times (some say 21), but often the vampires have solved the same challenges with different quirks of biochemistry. The challenge of detoxifying tyrosine, however, might be a problem that a lot of lineages have solved in unusually similar ways, Oliveira proposes.

First stabs at a weapon to disable the common chemistry are compounds that inhibit an enzyme called HPPD. The enzyme shuts down tyrosine breakdown, not just in the kissing bug but also in a kind of tick and in the female Zika-spreader *Aedes aegypti* mosquito. When tested, the treatment didn't harm milkweed bugs or mealworms.

## Bad blood

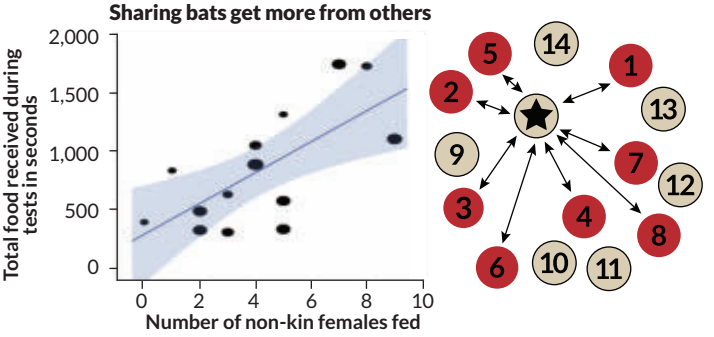
Tyrosine is just one of the nutrients turned toxic by the massive size of blood binges. In the real world, a vampire's ability to excrete wastes is much more important than some fictional power to hoist trucks.

Nephrologist Jonas Axelsson of the Karolinska Institute in Stockholm and colleagues are studying kidney function in vampire bats versus cousin species that live on fruit or nectar. Human diets typically feature some 50 to 120 grams of protein a day, but eating like a vampire bat would boost a 70-kilogram human's intake to some 6,000 grams of protein a day. That protein overdose means these bats have blood concentrations of protein-metabolism waste products such as urea that would be a short route to kidney failure in humans.

Yet the vampire bats are fine. Their kidneys are about the same size as other bats' kidneys, Axelsson says. Vampire bats devote more of their space to the long tubules that deal with reabsorbing useful substances from just-made urine, he notes.

Much of the protein in blood is hemoglobin, the iron-containing marvel molecule that ferries oxygen around the body and helps vertebrates live big and bold. Yet digesting so much hemoglobin in a hurry can free a massive, potentially

The common vampire bat is a blood licker. Razor teeth nick flesh so the bat can lick up the gently welling blood.




**Networking** Captive vampire bats that shared blood with non-kin reaped benefits. Hungry females that donated to more bats tended to receive more regurgitated blood from others later (left). The diagram at right shows one bat's feeding network. Red circles are bats a hungry bat (star) had donated to in the past. Two-way arrows show reciprocity.

poisonous dose of iron into the bloodstream. A healthy man makes his doctor happy with blood iron concentrations around 127 micrograms per 100 milliliters. Yet concentrations up to 200 times higher don't seem to harm fishes called lampreys during their larval years, measurements from various species suggest. The larvae pick up iron while burrowing and eating anything that floats along. When sea lampreys (*Petromyzon marinus*) mature, growing their jawless toothy gapes and sucking blood of other fishes, iron concentrations in blood drop — to about 10 times healthy human levels.

At first, a lamprey sticking to skin feels like "a moistened suction cup on your face," says lamprey biologist Margaret Docker of the University of Manitoba in Winnipeg, Canada. She has permitted one exploratory kiss on her cheekbone from a blood-feeding silver lamprey (*Ichthyomyzon unicuspis*) found in North American lakes and streams. Only half the world's 38 lamprey species suck blood.

Lampreys can generate a good grip; some even mouth-suck their way up vertical waterfalls or dams. In the very unlikely event of a fish on the face, "the key is to dislodge it ... before it starts to rasp in with the teeth on its tongue or oral disk and before it secretes its anticoagulants," Docker says. A little prying with a fingernail breaks the suction.

Lampreys may have gone parasitic early in the history of vertebrates and so have had a long time to evolve their vampiric specializations. A small fossil from Devonian times, some 360 million years ago and long before dinosaurs arose, shows an oral disk with 14 evenly spaced teeth, already looking very capable of draining blood.

Studies of the modern species' blood-feeding physiology got a solid source of new data in 2013 when an international team decoded the genetic instruction book of the sea lamprey, a notorious invader of the Great Lakes. Docker hopes for more work on lamprey detox tricks, such as the liver enzyme superoxide dismutase, which increases as concentrations of iron in the liver rise in adult pouched lampreys. At this stage, liver cells are akin to those in people suffering from a potentially fatal iron-metabolism disorder called hemochromatosis.

Another big reason for studying real vampires, as if scientists need another, is the possibility of finding new insights into human metabolic disorders.

## Not enough

Blood may have lethally too much of some things, but lethally too little of others. "Vampires don't really have it that easy," muses ecological microbiologist Rita Rio of West Virginia University in Morgantown.

Blood lacks B vitamins, she explains. Animals need these as essential nutrients for a wide range of basic bodily chores, such as gene regulation, cell signaling and amino acid breakdown. Yet animals can't make their own supplies. Rio's favorite vampire flies get around this problem with tiny live-in help.

"I have loved tsetse flies ever since I first learned about them," she says. She's speaking of sub-Saharan Africa's *Glossina* flies' "really cool biology," not their ability to spread the parasite that gives humans and some other vertebrates potentially fatal sleeping sickness.

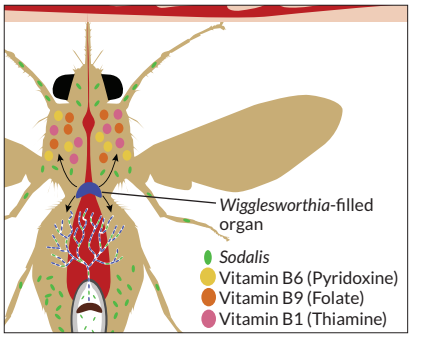
Tsetse flies look like robust house flies but live very differently. Instead of the typical low-involvement insect motherhood of laying many little eggs and leaving them to their luck, a female tsetse fly has just one offspring at a time. A single egg hatches inside her, and as it grows, it draws sustenance from "milk" glands inside the mother fly. "You'll see her getting chubbier and chubbier," Rio says. A mother sometimes gives birth to a youngster bigger than she is. The youngster at that point has only its pupal stage to go before it reaches sexual maturity. "It would be like me giving birth to a 12-year-old," Rio says.

As the mom fly gives her tween a pampered start in life, she also passes along an infection the youngster will need to reproduce on its nutritionally sketchy, all-blood diet. Each larva emerges with its own rod-shaped bacteria called *Wigglesworthia*, a bit on the chubby side themselves. The bacteria churn out B vitamins and flourish inside a special organ that grows inside the fly. The tsetse fly version of this organ, called a bacteriome, "looks like a little doughnut around the digestive tract," Rio says.

The interplay between fly and microbes has come to fascinate evolutionary biologists, as genes in both bacterium and host change across generations, sometimes breaking down or taking on odd functions, depending on what the other partner is doing. In the September *Genome Biology and Evolution,* Rio and her colleagues published a study of the molecular activity of both tsetse flies and their *Wigglesworthia* in the wild.

## Low-fat bats

Another downside of blood is its low fat content, at least from the vampire bat point of view. Extra cargo on a small flying mammal is limited to a mere 20 to 30 percent of the animal's predinner weight, so a small, low-fat meal won't fuel the bat for very long. A common vampire bat (*Desmodus rotundus*) can't survive three days without drinking blood, says evolutionary biologist Gerald Wilkinson of the University of Maryland in College Park. That's one of the forces pushing the bats to develop social networks of blood regurgitators.




**Little helpers**
Tsetse flies (pregnant female, above) can survive on an all-blood diet thanks to symbiotic bacteria. In an organ (blue, right) ringing the fly midgut, *Wigglesworthia* bacteria churn out B vitamins, including B1. Both the fly and resident *Sodalis* bacteria need this vitamin, also called thiamine.

Needing backup blood is no slur on this vampire's superb adaptations to feeding on large vertebrates. The razor-toothed mammal is one of three blood-feeding bat specialists, all native to the warm latitudes of the Western Hemisphere. The first wild *D. rotundus* Wilkinson studied, on a ranch in Costa Rica, "would often just fly up and land on the back of a horse," he says. The bat has a fleshy little nose, "like a pig," with heat-sensing ability useful in finding where warm blood flows close to the body's surface. Actually getting that blood "was a very nontrivial thing" for the bats, he says. A bat routinely spent half an hour selecting a spot, clipping down horse hair if necessary, nicking out a tiny divot of flesh and then licking the wound, often while urinating, all without waking the horse. Revisiting a wound on another night appeared to be faster than prepping a new site. Wilkinson realized one night that the bat he was watching was feasting on the same horse it had fed on the night before, even though the horse had been moved to a different pasture.

The bat's saliva has impressive anticoagulant powers, Wilkinson reports. "I've been nipped a few times and the blood was hard to stop," he says. "People who have been fed on will wake up and there's a pool of blood — and the blood is often from after the bat left."

Compared with bats of other species, the common vampire bat may even seem to have superpower moves: Instead of just flying, it easily runs on the ground.

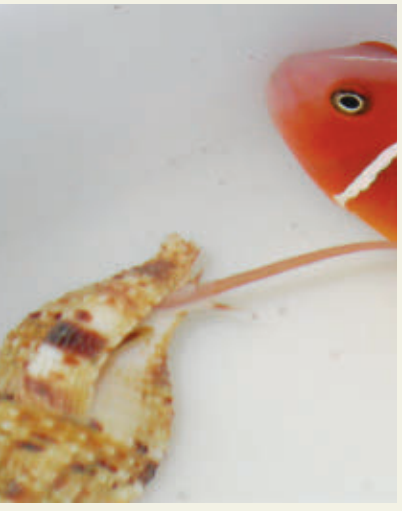
When a hungry bat can't find a meal for a night, the accomplished blood seeker may get a bit of blood from a luckier roost mate. Positioned facing each other mouth to mouth, "one animal is motionless and the other animal is licking," Wilkinson says.

In his early experiments with captive bats, he found animals willing to regurgitate on occasion for a hungry bat with no kinship connection. For decades, researchers have debated

FROM TOP: GEOFFREY M. ATTARDO; R. RIO *ET AL*/*TRENDS IN PARASITOL.* 2016

## Many shades of vampire

The real world of blood feeding is much more varied than fictional vampires' all-or-nothing menus. Drinking blood can be a full-time or a sometimes urge.



### Cast a spell

*Colubraria muricata* snails are experts at sucking blood from fish. Found from South Africa to French Polynesia, the snail creeps toward a sleeping fish and extends a long feeding tube (shown), with fish blood pressure probably delivering the meal. The snail secretes a complex cocktail that may include an anesthetic to keep the donor passive for the duration of a drink, says Marco Oliverio of Sapienza University in Rome.

### Furtive drinkers

Sometimes considered helpful partners, Africa's oxpeckers (*Buphagus*) glean ticks and other arthropods from African grazing animals. Red-billed oxpeckers (*B. erythrorhynchus*, shown) also eat earwax, dung, urine — and blood. In food tests on donkeys, birds chose to feed on wounds even when the birds' favorite ticks were offered, Tiffany Plantan of University of Miami in Florida and colleagues found.

### Kids' stuff

An adult *Antricola marginatus* tick probably feeds on bat guano, but youngsters riding on mom's back (shown) readily leap off to drink blood if warm mammals are nearby. A mom may "feed" her young by climbing near bats, Marcelo Labruna of the University of São Paulo in Brazil and colleagues proposed after observing moms and young in a Yucatán bat cave in Mexico. — *Susan Milius*

whether it's fair to consider vampire bats as examples of natural altruism. For the latest published experiments, Wilkinson's student Gerald Carter, at the Max Planck Institute for Ornithology in Konstanz, Germany, as of November, put together bats from unrelated zoo populations. He fed them blood (collected from a slaughterhouse, not anybody's favorite part of doing science) and then created short artificial food crises, recording dozens of observations of blood sharing.

Looking at all these examples of sharing, kinship didn't matter, Carter and Wilkinson concluded. In captivity at least, a vampire will help a starving roost mate who's not a relative.

Carter even did an elaborate test of how a starving vampire reacts when its main go-to pal for emergency regurgitation "betrays" it by not helping. To simulate betrayal, Carter removed the potential helper from the group so it did not feed its starving roost mate. Then on another night, he flipped the roles. The bat that had not helped its pal was now the hungry one in need of that pal's regurgitation.

In general, no hard feelings. The partner who was forced to defect often got fed regardless. The evidence so far looks as if vampires are hedging their bets in sharing blood, Carter, Wilkinson and Damien Farine of Max Planck proposed in the May *Biology Letters*. Bats that shared with many partners over the long run ended up receiving more blood when it was their turn for trouble. In an uncertain world, this advantage might favor helping non-kin. Vampirism may work as a force for generosity.

## Way beyond bats

Baby vampire bats go for blood right away, licking their mothers' mouths for red regurgitation within minutes of birth. And there are many more vivid variations on vampirism (see sidebar at left).

There's blood feeding as a mix of practicality and mate monopolization in a vast dark and dangerous ocean. In some deep-sea ceratioid anglerfishes, males stay miniature and upon finding a female meld tissue with her giant body and thereafter live off her circulatory system. The male essentially makes her a hermaphrodite with a sperm organ ready when she needs it.

There's also blood feeding by proxy. The jumping spider *Evarcha culicivora* hunts mosquitoes, preferably those engorged with human blood. There's even blood feeding as an impossible dream. Male mosquitoes sip flower nectar, but when scientists served the mosquitoes blood soaked cotton, they ate readily. Given nectar as an alternative, males still went for blood instead, even though they died early.

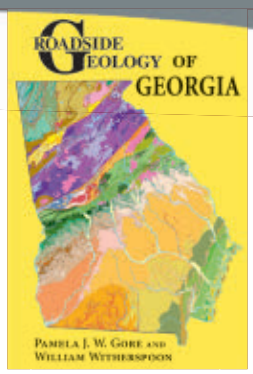
And there could be even more vampires out there that science hasn't discovered yet. All it might take is someone sticking a thumb into a collecting vial. ■

## Explore more


- Marcos Sterkel *et al*. "The dose makes the poison: Nutritional overload determines the life traits of blood-feeding arthropods." *Trends in Parasitology*. August 2017.


FROM TOP: COURTESY OF M. OLIVERIO; ANDREANITA/ALAMY; M.B. LABRUNA *ET AL/J. PARASITOL.* 2012

# GEOLOGIC ROAD TRIP OF THE MONTH






## CLOUDLAND CANYON STATE PARK

Cloudland Canyon State Park, one of the Seven Natural Wonders of Georgia, is 6.4 miles east of I-59. Turn left (north) onto Cloudland Canyon Park Road and continue 1.5 miles to the overlook parking area.

From the Point you can see Lookout Valley beyond the canyons, with its lush pastures underlain by Ordovician-age carbonate rocks. The ridge in the distance beyond the valley is Sand Mountain.

The layers of sandstone in the bluffs across the canyon are not fully continuous. That's because there are many independent bodies of sandstone, each the product of a particular even. You can see such a sandstone body, with its convex bottom projecting below nearby sandstone layers, directly across the canyon from the Point.

At the Point you are standing on crossbedded sandstone. What resembles wood grain beneath your feet is actually the eroded top edges of numerous crossbeds. The edges of these former ripples are curved in a U shape because they formed in a stream and were sculpted as they migrated; the concave portion points downstream. On the way back to the parking lot, at the first steps you encounter, look to your left. Here a cross section of the crossbeds is exposed. The orientation of the crossbeds indicates the stream that deposited them flowed south, toward the parking lot.

There is a path to the bottom of the canyon where you can see two waterfalls on Daniel Creek. The complete hike will take about ninety minutes round-trip. From the parking lot, head left along the canyon rim. Continue in the same direction (south) along the Waterfalls Trail and follow the switchback that heads north. Just below the switchback is a long outcrop about 15 feet high, which, where you first see it, is made entirely of crossbedded sandstone. Continuing northward down the path and tracing the crossbedded rock, you'll see that it ends against a sharp boundary that slopes to the north. Above and north of the boundary is unlayered sandstone. As the trail rounds a corner, the same massive sandstone crops out as a huge overhanging rock, underneath which twenty people might easily take shelter.

*Crossbedded strata (lower right) in Cloudland Canyon State Park are cut by an unlayered sandstone. The crossbeds were deposited by a current that flowed to the right.*

The thick sandstone in the overhanging rock is a cross section of an ancient river channel frozen in time. During Pennsylvanian time the river eroded tens of feet down into the older sand deposits (crossbedded sandstone), cutting the large, convex-downward shape of the channel. The absence of obvious internal layering within the channel sandstone indicates that at the end of its life, this channel probably filled rapidly, unlike the layered, crossbedded sandstone surrounding it. Crossbeds form slowly, as the sand in a river or stream channel migrates over time. Studies of modern rivers show that such rapid filling can occur during a major flood. If a natural levee breaks upstream, the flow can cause a river to abruptly change course and abandon a portion of its channel. The pebbles protruding from the bottom of the rock overhang are further evidence that this was a river channel. Pebbles are concentrated on river bottoms, where they tend to roll along in the current. Impressions of fossilized wood (presumably waterlogged as it was carried downstream) are also present.

Both the 50-foot upper falls (Cherokee Falls) and the 90-foot lower falls (Hemlock Falls) on Daniel Creek developed where the stream crosses from erosion-resistant sandstone into easily eroded shale below. The shale is the dark rock with thin beds in the cliffs below the falls. It forms flat chips as it erodes. The shale cliffs behind the waterfall continually crumble away, removing the support for the tough sandstone ledge at the top. As a result, the position of each waterfall retreats upstream over time. The bed of Daniel Creek is filled with sandstone boulders—some nearly house sized—from ledges that have collapsed in the past.

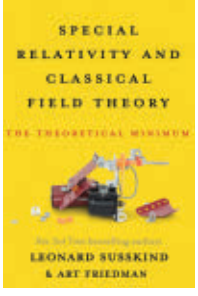
*The canyon cut by Daniel Creek. Sand Mountain is visible in the distance.*

BOOKSHELF

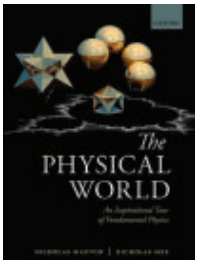
# New books don't censor math behind reality

Many books about science are meant to be pleasure reading. Such books attempt to convey the wonder and fascination and excitement of science, and ideally some of the substance as well. After all, good popular science writing is not only engaging and entertaining, but also informative. But even very informative popular books are not designed to be fully educational about the science in technical detail. Popularization by its very nature requires omission of detail and simplification in description.

As a result, many readers of popular science never get a true picture of how intricate and deep the corpus of scientific knowledge can be. For physics in particular, the "big ideas" conveyed via clever analogies and metaphors rarely reveal the richness of the mathematical foundations underlying them. It is equally rare for writers who do include equations to dissect them and analyze how they are derived. After all, most authors early on were advised of the old publisher's axiom that each equation cuts a book's sales in half.




**Special Relativity and Classical Field Theory**
*Leonard Susskind and Art Friedman*
BASIC BOOKS, $30




**The Physical World**
*Nicholas Manton and Nicholas Mee*
OXFORD UNIV., $38.95

Fortunately for those who like their physics raw, with the math uncensored, publishers sometimes rescind the keep-equations-to-a-minimum rule for books that remain accessible to dedicated readers interested in physical reality's mathematical foundations.

One such book, *Special Relativity and Classical Field Theory*, is the third volume in Stanford University physicist Leonard Susskind's "Theoretical Minimum" series. Previous volumes covered classical physics (*SN: 4/20/13, p. 30*) and quantum physics (*SN: 6/14/14, p. 29*). In the latest, Susskind (with Art Friedman) analyzes the mathematical apparatus of Einstein's special theory of relativity, which describes matter in uniform motion, and the physics of fields, such as those explaining electricity, magnetism and associated phenomena.

As in previous volumes, Susskind walks you through the basics of each topic and builds the necessary math from scratch. It helps if you've read the earlier books (especially the first, which focuses on classical mechanics). But either way, your prime requirement for getting much benefit from this book is comfort with sophisticated mathematics.

Susskind is meticulous in explaining each step of applying the equations to the physical phenomena he describes, and he excels in explaining why the math works the way it does. Nevertheless, if matrices and tensors and summation indices give you headaches, prepare for a migraine. If you're intrepid enough, though, you'll emerge with a much deeper appreciation for the true meaning of Einstein's relativity, Maxwell's equations and many other aspects of fundamental physics.

For more detail (if perhaps less help), you could turn instead to *The Physical World*, by English physicists Nicholas Manton and Nicholas Mee. They have composed a treatise of impressive scope, encompassing all aspects of fundamental physics in one nearly 600-page volume. They start with the laws of motion and move on to Maxwell's equations and fields, special and general relativity, quantum physics, atoms and molecules, thermodynamics, nuclear and particle physics, astrophysics and cosmology. Their text is straightforward and clear but dry and technical — equations are often embedded in a sentence as though they were words. It's not a recipe for speed reading, but it is a thorough presentation of the rigorous math underlying a vast spectrum of natural entities and phenomena.

Both books emphasize the importance of variational principles in describing nature, such as the principle of least action. As Manton and Mee stress, "least action" refers to a certain efficiency in how nature operates; the principle is in many ways more fundamental than some physical laws. It applies in vastly diverse contexts; it even helps bridge the divide between classical and quantum physics. It is conceptually superior in that many other facts of physics (such as laws of motion) can be derived from it. But there is a cost, as Manton and Mee note: the need for "more sophisticated mathematical technology." It's simply inescapable that understanding the physical world precisely requires a grip on math that cannot be achieved without considerable mental effort.

Both of these books require such effort — they are not recreational beach reads. But they do make the rewards of deeper understanding attainable for anyone sufficiently motivated to pay the price. — *Tom Siegfried*

BOOKSHELF

# Species resurrection raises ethical questions

A theme park populated with re-created dinosaurs is fiction. But if a handful of dedicated scientists have their way, a park with woolly mammoths, passenger pigeons and other "de-extincted" animals could become reality.

In *Rise of the Necrofauna*, writer and radio broadcaster Britt Wray presents a comprehensive look at the unprecedented technical difficulties of raising the dead, plus the deep philosophical questions surrounding de-extinction.

The aim of current de-extinction efforts is to use gene-editing tools to engineer living species to re-create extinct cousins, such as engineering a

A core of seafloor sediment collected off the coast of Jamaica by geologist Jeff Donnelly holds clues to prehistoric hurricanes.

BLINK FILMS

TELEVISION

## Storm documentary proves timely

In 1780, a powerful hurricane swept across the islands of the Caribbean, killing an estimated 22,000 people; 5,000 more died of starvation and disease in the aftermath. "Our planet is capable of unleashing extreme chaos," begins the new *NOVA* documentary "Killer Hurricanes," set to air November 1 on PBS.

To describe the human impact of such powerful tropical cyclones, the documentary primarily focuses on two storms: the Great Hurricane of 1780 and Hurricane Matthew, a Category 4 storm that slammed into Haiti and Cuba last October. Before the devastating 2017 Atlantic hurricane season (*SN Online: 9/21/17*), Matthew was considered the biggest Atlantic storm of the last decade.

Still, the film's larger message remains timely: Studying the hurricanes of the past can offer insights into storms of the future — and, hopefully, help coastal and island communities prepare for such events.

The documentary describes the work of researchers as they examine both human and geologic records to track past cyclones. Because the Great Hurricane occurred during relatively recent history, researchers can use eyewitness accounts and ship records to estimate not only the size of the storm, but also to track its path and calculate the storm surge.

But geologists such as Jeff Donnelly of the Woods Hole Oceanographic Institution in Massachusetts and Amy Frappier of Skidmore College in Saratoga Springs, N.Y., are looking deeper into the past. Donnelly finds physical traces of prehistoric hurricanes buried in seafloor sediments, while Frappier detects chemical traces in stalagmites growing in caves across the Caribbean. These data reveal a troubling pattern: The frequency of strong hurricanes distinctly increases when ocean temperatures are warmer. What's more, hurricanes' paths have shifted northward over the last 450 years, moving closer to the contiguous United States.

As the film notes, ocean waters are now warming at a rapid rate. Meanwhile, sea levels are rising, and the water in the oceans expands as it warms. Both effects will augment the impact of storm surge from such cyclones.

**"Killer Hurricanes"**
**PREMIERES NOVEMBER 1**
PBS | *NOVA*

"Killer Hurricanes" doesn't break much new ground, and the film's stark conclusion about the future paths and intensities of powerful cyclones is one that climate scientists have long been signaling. But coming on the heels of a deadly hurricane season, and with the United States' future participation in the Paris climate accord in limbo (*SN Online: 6/1/17*), the film may serve as a powerful reminder of the human cost of climate change. — *Carolyn Gramling*


**Rise of the Necrofauna**
*Britt Wray*
GREYSTONE BOOKS, $26.95

woolly mammoth from an elephant. This "molecular magic" is not the effort's main limitation, de-extinction scientist George Church claims in the book. Instead, the biggest hurdles are the same that conservationists face when reintroducing endangered species to native habitats.

As Wray explains, habitats for many extinct creatures are gone or conditions are perilous. Take the gastric-brooding frog. The species, known for converting its stomach into a uterus and vomiting tadpoles, was driven to extinction in 1983 by chytrid fungal infections. A project to clone the frog managed to get the cells of another frog species to replicate gastric-brooding frog DNA — a promising first step in restoring a gone-too-soon species. Still, Wray wonders, "Is it really the right time to clone the gastric-brooding frog when the chytrid fungus that first killed the species continues to annihilate amphibians around the world?" Not to mention the hostility other reanimated species might face if their interests run counter to those of humans sharing a habitat.

Another ethical dilemma is whether it's better to invest in bringing back extinct animals or in pulling endangered species back from the brink. For instance, if scientists could engineer gastric-brooding frogs to resist chytrid fungus, then researchers could make living amphibians fungus-proof, too. Or tricks borrowed from de-extinction could inject genetic diversity into dwindling populations, like those of black-footed ferrets on the Great Plains. Church and others, though, argue that de-extincting animals sparks the imagination in ways that merely maintaining endangered populations doesn't.

Wray doesn't pick a side until the end, and even then, she presents the full nuance of the "can we/should we" questions — many of which have no easy answers. — *Tina Hesman Saey*

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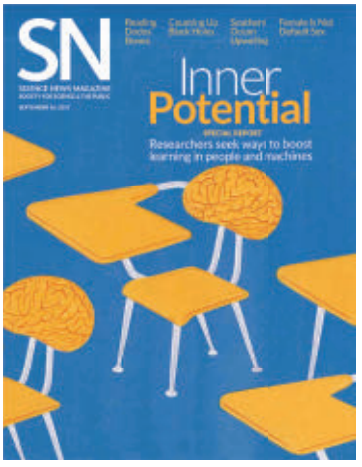


SEPTEMBER 16, 2017

## Bittersweet science

A spoonful of two artificial sweeteners helps the bitterness go down. But the reason has been a mystery, until now. In the most-viewed *Scicurious* blog post for September, "Two artificial sweeteners together take the bitter out of bittersweet" (*SN Online: 9/14/17*), **Bethany Brookshire** reported that each sweetener blocks the other's bitter taste. Read more about this saccharin science at bit.ly/SN_Bittersweet

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### Brain boost

*It's possible that therapies such as external brain stimulation and neurofeedback, as well as some drugs, may one day boost brain flexibility. A new line of research suggests flexibility is important for learning, **Laura Sanders** reported in "Flex time"* (SN: 9/16/17, p. 22).

Online reader **Glenn** wondered if drugs for Parkinson's disease and Huntington's disease that help with movement problems could also remedy learning difficulties that accompany these conditions.

"Currently, there are no drugs that can stop or reverse the neural damage from either disease, though some drugs help with symptoms," **Sanders** says. "But scientists are studying whether the Parkinson's drug levodopa, which can ease movement symptoms, can also influence brain functions such as memory, quick thinking and learning."

### The skinny on sea snakes

*Polluted waters may be driving more sea snakes to go all black, a sign of an evolutionary phenomenon called industrial melanism, **Susan Milius** reported in "Polluted reefs may favor dark snakes"* (SN: 9/16/17, p. 14).

"Is it possible that increased melanin production in sea snakes is a sign of arsenic poisoning as it is in humans?" **Mark Moberg** asked. He also wondered if an observed increase in algae that adhere to the snakes' skin might also be a sign of arsenic poisoning.

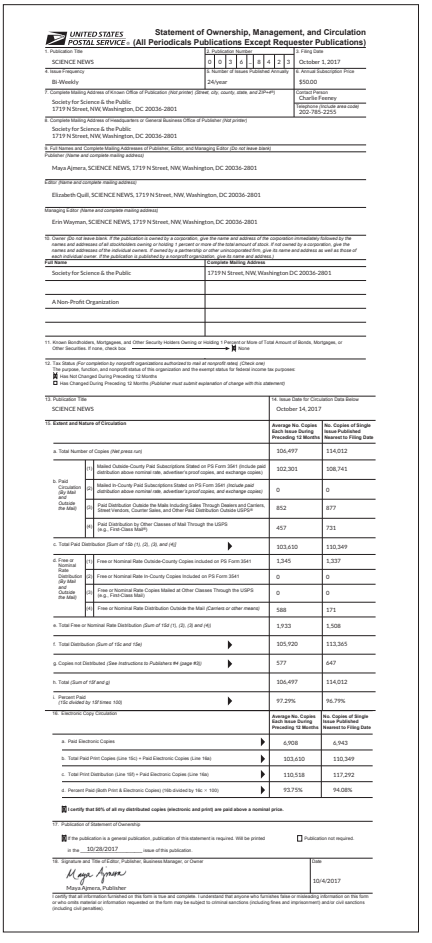
The higher frequency of black-bodied snakes seems to be due to genetics, not arsenic poisoning, says **Rick Shine**, an evolutionary biologist at the University of Sydney. **Shine** points to genetics because "a snake doesn't change its color from the time it is born until it dies," he says. And the higher incidence of algae on dark surfaces doesn't just apply to the snakes. The researchers found that algae also congregated on painted pipes in the snakes' environment. "It's a simple attraction to the color, not an effect of the poison," he says.

### Hit and run

*Scientists spotted evidence of two photons ricocheting off one another at the Large Hadron Collider, **Emily Conover** reported in "Aloof light particles nudged to interact"* (SN: 9/16/17, p. 7).

Online reader **David Laing** wondered how photons, which are theoretically massless, can transform into particles with mass that may interact.

Massless particles with enough energy can convert some of that energy into mass, **Conover** says. "Remember Einstein's equation $E=mc^2$! But photons can briefly convert into massive particles even if they don't have enough energy thanks to Heisenberg's uncertainty principle." A photon can convert into an electron and a positron for a brief instant before those particles revert back into a single photon. "These so-called 'virtual' particles allow light to scatter off of other light," she says.



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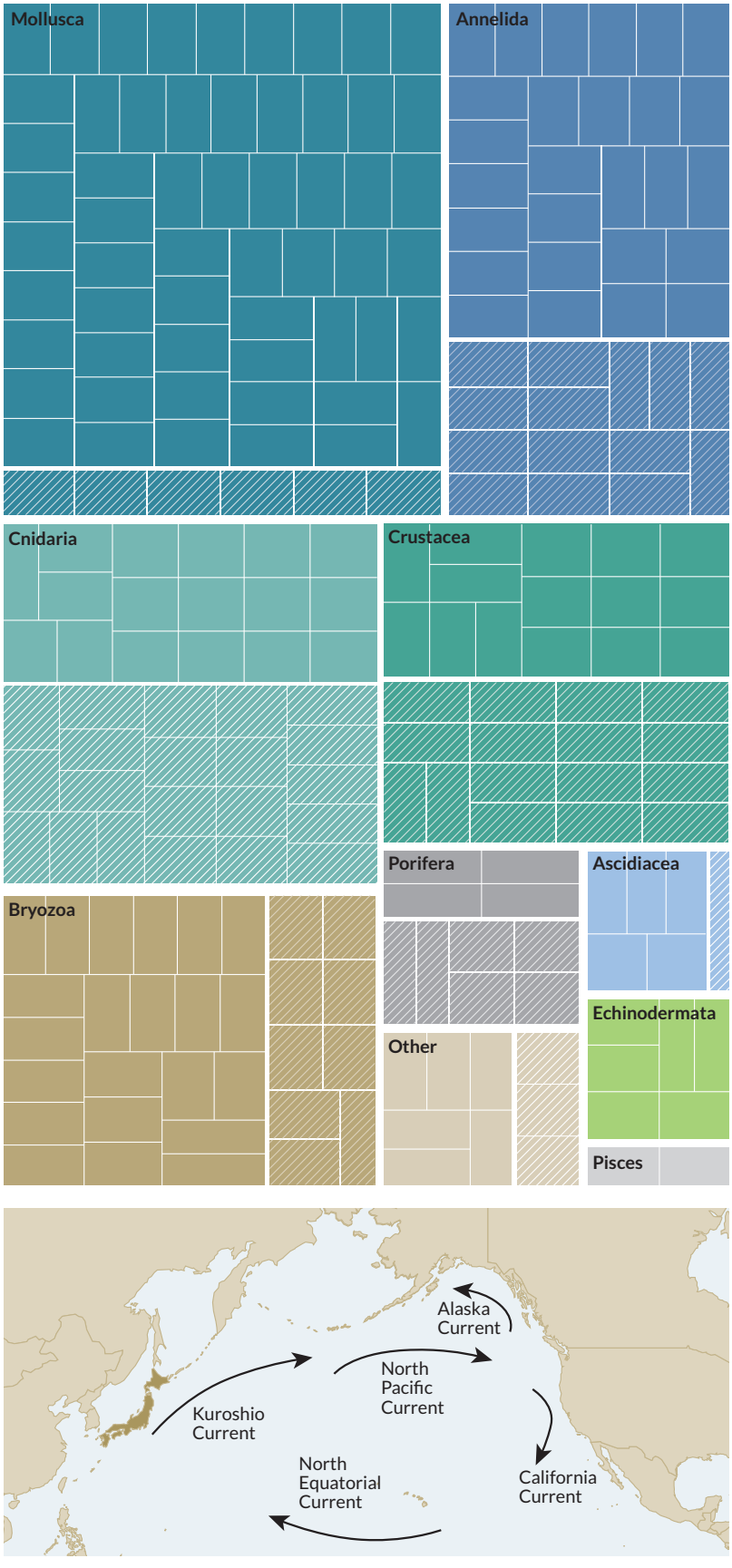


# Debris arrivals divvied up

Life's great diversity has revealed itself in more than 600 pieces of floating tsunami debris that have landed on the western coast of North America. Of nearly 300 living animal and protist species documented on the debris (see Page 4), which crossed the Pacific Ocean following Japan's destructive 2011 tsunami, researchers analyzed in detail 237 species, which include larger invertebrates and two fish. The critters represent 15 taxonomic groups, as defined by the scientists in the Sept. 29 issue of *Science*. (Each box at left signifies a living species; colors are different groups.)

Most of the species were mollusks, including marine snails, nudibranchs and oysters. Mollusks were followed by annelids (segmented worms), cnidarians (including sea anemones), bryozoans (moss animals that sometimes resemble coral), crustaceans and others. Some species, such as sea anemones and limpets, were able to reproduce and maintain multiple generations on these debris "islands."

The unprecedented marine migration was possible because much of the rubbish caught up in the Pacific currents (shown at bottom left) was durable, made of plastic or fiberglass. "Years ago there were other natural disasters that potentially produced debris, but the debris was, well, organic," says Nir Barnea, the regional coordinator for the National Oceanic and Atmospheric Administration's marine debris program in Washington and Oregon. "Now we have plastic materials, man-made materials that remain in the marine environment for many years."

About 68 percent of the animal species (solid colors) had never been documented along North America's Pacific coast, while the others (crosshatched) occur naturally or were previously introduced. If established, alien species may threaten native marine habitats, but it could take years to detect such effects.

Despite intense efforts, the researchers know they didn't record all of the species arrivals. "We assume that there are a good deal more species that arrived that we simply never saw," says study coauthor James Carlton, a marine scientist at Williams College in Mystic, Conn. "Just imagine the thousands, or maybe tens of thousands, of objects that landed in North America and Hawaii with living Japanese species." — *Mariah Quintanilla*

DATA: J.T. CARLTON *ET AL*/*SCIENCE* 2017; ART: E. OTWELL, C. CHANG

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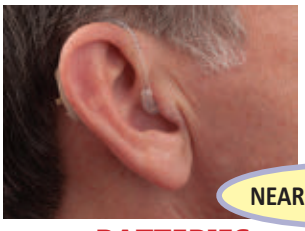

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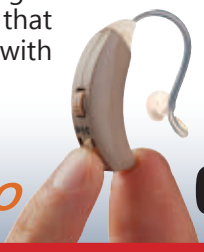

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