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SCIENCE NEWS MAGAZINE
SOCIETY FOR SCIENCE & THE PUBLIC
DECEMBER 10, 2016

Parkinson's Gut-Brain Connection

Supersolid Success

Galaxies Gone Dark

A Protein for Memory

# Number Smarts

## Animals show their skills at quantitative tasks

VOL. CLVII....No. 30,000 **The Stauer Times** "It's About Time"

*News Flash....*

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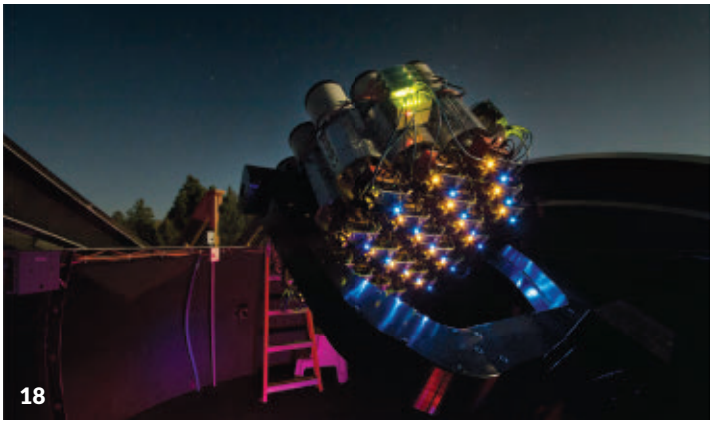
18

## Features



## News




16


4

## Departments



**COVER** Dogs are able to judge quantity, as can plenty of other animals. *imageBROKER/Alamy*

CLOCKWISE FROM TOP LEFT: P. VAN DOKKUM; MATTHEW JACOBS; FLIP NICKLIN/MINDEN PICTURES/GETTY

# Scientific success depends on finding light in darkness

Without light, we cannot see. That's why "dark galaxies" have eluded astronomers for so long. Two years ago, these star-starved entities were virtually unknown. But scientists now have better ways of seeing, even in dim conditions. New telescopes that can detect the faint light from these mysterious galaxies have enabled scientists to chalk up a considerable list: Dark galaxies seem to be much more common than anyone had thought. One rivals the Milky Way in size but holds only a hundredth as many stars.

Cataloging these dark galaxies, as Christopher Crockett reports on Page 18, is just the beginning. Scientists still don't know how such galaxies might have formed or how their small populations of stars can fend off the gravitational grabs of other galaxies. Understanding dark galaxies will take more time and more intense study of their faint light.

Cleverly built telescopes may allow us to examine the cosmic darkness, but a different type of cleverness entirely is required to delve into the minds of animals. Specifically, researchers trying to understand the evolutionary roots of mathematics must resort to complex tests for evaluating how animals judge quantities, Susan Milius reports on Page 22.

Counting seems an all-too-human concept, and yet many creatures can reliably pick out a greater number of treats. Figuring out how animals are making such a choice (is it surface area? volume? number?) has frustrated researchers and occasionally triggered disagreements. But the latest studies show signs that many animals do have some quantitative sense, even if it's far less sophisticated than our own.

Much less illuminating are the results that supposedly would have provided the final answer about heart health risks posed by the anti-inflammatory pain medicine Celebrex. Like Vioxx, which was taken off the market years ago after it was linked to heart problems, Celebrex (generic name celecoxib) is what's known as a COX-2 inhibitor. Many experts were concerned that the problems with Vioxx might also show up in people who took Celebrex. But there were little data, so the U.S. Food and Drug Administration asked for a large study to clear up the question. When the results were reported in November at a meeting of the American Heart Association, they brought little resolution, Laura Beil reports on Page 6. Despite finding no elevated heart risk from Celebrex use, and fewer gastrointestinal side effects compared with ibuprofen and naproxen, the study was not done as cleverly as it needed to be. It enrolled people already at low risk of heart problems, for one. Dosages of medicines shifted during the long study. Many taking Celebrex dropped out before the study was completed. Far from settling the issue, the research leaves many questions unanswered.

In so many areas, science succeeds — seeing into the darkness, exploring the unknown and investigating fantastical ideas. But sometimes the signal is faint, the tools we use too crude, the logic shaky, the deeper understanding still elusive. That's when scientists need to be more clever, more persistent, more wedded to reason and committed to revealing whatever truths can be found out there in the light. — *Eva Emerson, Editor in Chief*

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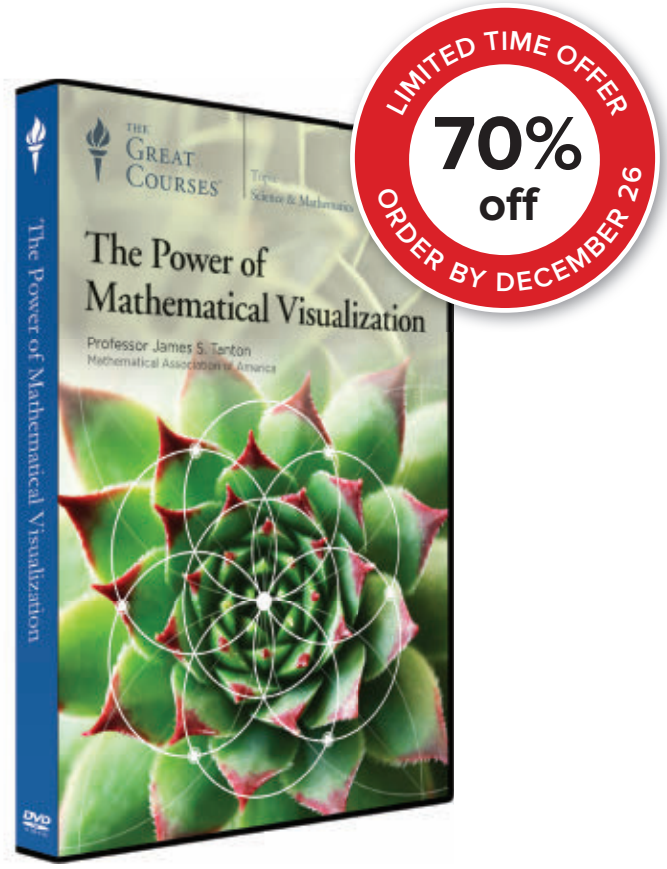


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Excerpt from the December 17, 1966 issue of *Science News*

50 YEARS AGO

## Atom blasts for gas

A pair of simultaneous nuclear explosions, one more than 1.6 miles underground and the other 1,000 feet above it, have been proposed as a way to extract huge quantities of natural gas from subterranean rock. Each blast would be ... about 2.5 times the size of the bomb used at Hiroshima. By breaking up tight gas-bearing rock formations, a flow of presently inaccessible gas may be made available.... A single-blast experiment, called Project Gasbuggy, is already planned.

**UPDATE:** On December 10, 1967, Project Gasbuggy went ahead, with a 29-kiloton nuclear explosion deep underground in northwestern New Mexico. The blast released natural gas, but the gas was radioactive. The area is still regularly monitored for radioactive contamination. Today, natural gas trapped below Earth's surface is often extracted via fracking, which breaks up rock using pressurized fluid (*SN: 9/8/12, p. 20*). Though less extreme, potential links to drinking water contamination and earthquakes have stoked fears about the technique.

MYSTERY SOLVED

## Blue is high-energy color for begonias

Iridescent blue leaves on some begonias aren't just for show — they help the plants harvest energy in low light.

The begonias' chloroplasts, which use photosynthesis to convert light into fuel, have a repeating structure that allows the plants to efficiently soak up light. This comes in handy for a plant that lives on the shady forest floor. The structure acts as a "photonic crystal" that preferentially reflects blue wavelengths of light and helps the plant better absorb reds and greens for energy production, scientists report October 24 in *Nature Plants*.

Some begonias get their color from tiny structures. Those structures help the plant convert dim light into energy.

Colors in plants and animals typically come from pigments, chemicals that absorb certain wavelengths, or colors, of

HOW BIZARRE

## Mount St. Helens is a cold-hearted volcano

Below most volcanoes, Earth packs some serious deep heat. Mount St. Helens is a standout exception, suggests a new study. Cold rock lurks under this active Washington volcano.

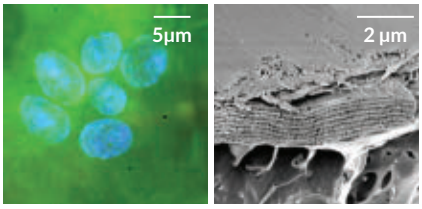
Using data from a seismic survey that included setting off 23 explosions around the volcano, geophysicist Steven Hansen peeked about 40 kilometers below Mount St. Helens. That's where the Juan de Fuca tectonic plate melts as it sinks into the hot mantle beneath the North American Plate. The melting fuels an arc of volcanoes lined up like lights on a runway. Mount St. Helens is part of the Cascade volcanoes arc, but it stands about 50 kilometers to the arc's west. Hansen, of the University of New Mexico in Albuquerque, and colleagues expected to see a heat source under Mount St. Helens, as seen under the others.

Mount Adams (background) has an obvious heat source, but Mount St. Helens (foreground) sits at the cold edge of the North American Plate.

Instead, thermal modeling revealed a wedge of a rock called serpentinite that's too cool to be a volcano's source of heat, the researchers report November 1 in *Nature Communications*. "This hasn't really been seen below any active arc volcanoes before," Hansen says.

This odd discovery helps show what the local crust-mantle boundary looks like but raises another burning question: Where is Mount St. Helens' heat source? Somewhere to the east, suggests Hansen. Exactly where, or how it reaches the volcano, remains a cold case. — *Beth Geiger*

FROM TOP: MATTHEW JACOBS; DMFOSS/ISTOCKPHOTO




Chloroplasts called iridoplasts (left) have microstructures that create a blue sheen. The structures (right, scanning electron microscope image) help the plants absorb low-level light.

light. In rare cases, plants and animals derive their hues from microstructures. Such tiny, regular architectures can be found within certain chloroplasts, known as iridoplasts, in begonias. As light bounces off these structures within an iridoplast, the reflected waves interfere at certain wavelengths (*SN: 6/7/08, p. 26)*, creating a blue, iridescent shimmer.

Those structured chloroplasts also offer a survival benefit, the new research shows: They help the plants collect light. In a hybrid of two species — *Begonia grandis* and *Begonia pavonina* — the structures enhance the absorption of green and red wavelengths by concentrating these rays on light-absorbing compartments within the iridoplasts. Importantly, the structures slow the light. The "group velocity," or the speed of a packet of light waves, is decreased due to interference between incoming and reflected light. The slowdown gives the plant more time to absorb precious sunbeams.

"These iridoplasts can basically photosynthesize at low-light levels where normal chloroplasts just simply could not photosynthesize," says study coauthor Heather Whitney, a plant biologist at the University of Bristol in England. Iridoplasts, however, can't hold their own in bright light. So begonias also have standard chloroplasts, which provide energy in plentiful sunshine. Iridoplasts act like "a backup generator" in dim conditions, Whitney says.

Other plants have structured chloroplasts, too, so begonias might not be alone in their feats of light manipulation. "Plants can't really run away from their problems," Whitney says. Instead, they have to be crafty enough to survive where they stand. — *Emily Conover*

SAY WHAT?

## Microcins \Mī-kro-sins\ n.

**Bacterial proteins that kill rival bacteria**

Competition is cutthroat in the crowded world of the intestines, so bacteria have evolved ways to kill rivals for a survival advantage. One strain of bacteria, called *Escherichia coli* Nissle 1917, has tiny proteins called microcins that may help *E. coli*'s host fight pathogens that cause gut inflammation, researchers at the University of California, Irvine report online October 31 in *Nature*.

Microcins take action only when bacteria are starved for iron, which happens in an inflamed gut. The proteins go after bacteria, many of them pathogens, that make iron-scavenging proteins, the researchers found.

*E. coli* Nissle's microcins killed diarrhea-inducing bacteria called *Salmonella enterica* in the guts of infected mice. Microcins also helped Nissle outcompete a different, nasty strain of *E. coli*. — *Tina Hesman Saey*

INTRODUCING

## Dragon dinosaur met a muddy end

A bizarre new birdlike dino was part of an evolutionary extravaganza at the end of the age of dinosaurs. And it was a real stick-in-the-mud, too.

Construction workers blasted *Tongtianlong limosus* out of the earth near Ganzhou in southern China. "They very nearly blew this thing to smithereens," says paleontologist Stephen Brusatte of the University of Edinburgh.

The find is one of six oviraptorosaur species discovered from roughly the same place and time — around 72 million to 66 million years ago. Like its feathered cousins, *T. limosus* walked on two legs and had a sharp beak. But each oviraptorosaur species had distinct skeletal quirks. *T. limosus*, for one, had a bony, domelike crest on its skull. Oviraptorosaurs were churning out lots of new species during the last stage of the Cretaceous Period, Brusatte says. *T. limosus* was part of "the final wave of dinosaur diversification before the asteroid came down and ended everything."

This particular fossilized animal lay in a bed of reddish-purple mudstone, preserved in an unusually awkward position: head stuck out, neck arched, wings outspread. It may have died after a desperate struggle to free itself from mud, the researchers suggest November 10 in *Scientific Reports*. That's actually how the dinosaur gets its name: *Tongtianlong limosus* is a mix of Chinese Pinyin and Latin meaning "muddy dragon on the road to heaven." — *Meghan Rosen*


This feathered dinosaur (illustrated) lived just before most dinosaurs were wiped out. Its fossil (left) is in an unusual, splayed position, suggesting a struggle to escape from mud.

CLOCKWISE FROM TOP: M. JACOBS *ET AL*/*NATURE PLANTS* 2016; ZHAO CHUANG, JUNCHANG LÜ/*SCIENTIFIC REPORTS* 2016

News

BODY & BRAIN

# Celebrex's risk to heart debated

## Critics say flaws undermine painkiller study results

**BY LAURA BEIL**

A long-awaited study on painkillers called nonsteroidal anti-inflammatory drugs has concluded that the three most commonly used carry a similar risk of cardiovascular complications. Yet critics say the study was too flawed to fairly compare them.

NSAIDs are the most widely prescribed class of drugs in the world. In the United States alone, doctors write more than 100 million prescriptions for NSAIDs each year.

Concerns about a type of NSAID called COX-2 inhibitors peaked in 2004 when the drug Vioxx was withdrawn from the market — a decision steeped in scandal because manufacturer Merck & Co. had initially hidden data that would reveal the drug's cardiovascular risks. A second COX-2 inhibitor, celecoxib, marketed by Pfizer Inc. as Celebrex, was allowed to remain on the market with the condition that Pfizer conduct a study to determine if Celebrex was as safe as two older NSAIDs, naproxen and ibuprofen.

The widely prescribed painkiller celecoxib (Celebrex) may pose no greater risk to the heart than do similar drugs such as ibuprofen (Advil) and naproxen (Aleve).


The study lasted 10 years and enrolled more than 24,000 patients but faced challenges. Doctors in European Union countries would not participate because they were worried about Celebrex's safety. Also, scientists hoped arthritis patients at high risk of heart disease would volunteer. But the study was ultimately dominated by those at low risk. And before it was over, about two-thirds of participants dropped out because their assigned drug was not controlling their pain.

A final analysis was presented November 13 and published online in the *New England Journal of Medicine*. After taking the drug at recommended doses for a minimum of 18 months, 4.2 percent of those on Celebrex had a major cardiac event — heart attack or stroke, for example — compared with 4.3 percent of those taking naproxen and 4.8 percent taking ibuprofen. The percentage of people who died from cardiovascular disease was highest for those taking naproxen, at 1.1 percent. But the differences among the three drugs were not statistically significant, said study leader Steven Nissen, chair of cardiovascular medicine at the Cleveland Clinic.

> "This was a trial that was supposed to compare the outcomes in high-risk cardiovascular patients, but we actually still have that question."
>
> ELLIOTT ANTMAN

Kidney problems, a known risk of taking NSAIDs, occurred in 0.7 percent of the Celebrex group, 0.9 percent of the naproxen group and 1.1 percent of the ibuprofen group. Also, those who took Celebrex had the fewest gastrointestinal complications, not a surprise because avoiding those complications was a key reason why the drug was developed.

Given the dangers of Vioxx, many doctors had dismissed Celebrex even before the Pfizer-funded study began, Nissen said. "Everybody thought they knew the answer." And even he was surprised when Celebrex fared better for cardiovascular risk than the other two drugs. Nissen said the results should be reassuring to patients taking the drug, which is now available as a generic.

But the study has its skeptics. "Does it give us answers? No, and that's the tragedy," said Garret FitzGerald of the Institute for Translational Medicine and Therapeutics at the University of Pennsylvania. Critical of the study design since its inception, FitzGerald wrote a commentary on the trial posted online November 13 in *Circulation*.

FitzGerald expected that, given the concerns about cardiovascular side effects, doctors would hesitate to enroll their high-risk patients in the study and that it would need to go on longer to collect enough data. "This is a trial in which most people dropped out before it was finished," he said. Also, doctors were allowed to bump up the doses of naproxen and ibuprofen if patients needed it for pain control, but the amount of Celebrex remained fixed. "It wasn't a fair comparison," he said.

The data also don't effectively account for which patients were taking aspirin when the study began, said Elliott Antman, a cardiologist at Brigham and Women's Hospital in Boston. Aspirin, which acts as a blood thinner, can lower the risk of heart attack. Because of how the drugs work, naproxen and ibuprofen — but not Celebrex — can interfere with the benefits of aspirin. Having more patients at high risk of heart attack would have increased the study's ability to detect risk, Antman added.

"This was a trial that was supposed to compare the outcomes in high-risk cardiovascular patients, but we actually still have that question," Antman said. And given the time and expense of this trial, there is unlikely to be another. New, less problematic pain drugs, he said, are "an urgent clinical need." ■

CELEBREX: PFIZER; OTHER NSAIDS: LILIBOAS/ISTOCKPHOTO

BODY & BRAIN

# Poor sleep tied to heart rhythm issue

## Insomnia, other problems may raise risk of atrial fibrillation

**BY LAURA BEIL**

Chronic sleep problems are associated with atrial fibrillation — a temporary but dangerous disruption of heart rhythm — even among people who don't suffer from sleep apnea. An analysis of almost 14 million patient records has found that people suffering from insomnia, frequent waking and other sleep issues are more likely than sound sleepers to experience a condition in which the upper chambers of the heart quiver instead of rhythmically beating, allowing blood to briefly stagnate.

"Even if you don't have sleep apnea, is there something about sleep disruption that puts you at a higher risk of fibrillation?" said cardiologist Gregory Marcus of the University of California, San Francisco. "We should put a higher priority on studying sleep." Marcus and Matthew Christensen of the University of Michigan presented the results November 14.

People with atrial fibrillation have double the risk of a heart attack and up to five times the risk of stroke. The heart condition can be a consequence of aging, but its prevalence is rising at about 4 percent per year for reasons that aren't totally clear. Over 5 million Americans are thought to currently have the condition.

Sleep apnea, which occurs when a person momentarily stops breathing during the night, can lead to atrial fibrillation and other health concerns. Identifying a risk of atrial fibrillation among people with no apnea is unexpected, said Richard Becker, director of the University of Cincinnati Heart, Lung & Vascular Institute.

Marcus, Christensen and colleagues analyzed data from three sources: a California database of almost 14 million patients, 4,600 participants in a sleep survey and over 5,700 people whose health was tracked for over a decade. Those data allowed the researchers to follow patients over time, tracking which came first — the fibrillation or various sleep issues.

Among the results: People who frequently woke had a 33 percent greater chance of developing atrial fibrillation in one analysis, and in another, a 47 percent higher chance of having the condition. In the survey group, insomnia upped the odds by 17 percent; among the California records studied, insomnia increased the odds by 36 percent. Analysis of a subgroup undergoing sleep studies showed that less rapid eye movement, or REM, sleep also was associated with a higher risk of fibrillation.

The study can't explain why a lack of sleep even with normal breathing might hurt the heart. The authors hypothesize that the mechanism is tied to the body's stress response. ■

MEETING NOTES

### Downside of yo-yo dieting is rise in heart disease

A new study shows just how bad yo-yo dieting might be.

Women who repeatedly lose and regain as little as 10 pounds may have a higher likelihood of sudden cardiac death and cardiovascular disease — even if their bodies stay within the range of recommended weight. The results are concerning because yo-yo dieting is more prevalent among people who are typically of healthy weight, said Somwail Rasla, an internal medicine resident at Brown University in Providence, R.I. He presented the results November 15.

Rasla and his colleagues analyzed data from more than 158,000 postmenopausal women who were followed for more than 11 years as part of the Women's Health Initiative. During that time, 83 women suffered from sudden cardiac death and 2,526 women died of heart disease. Yo-yo dieters of healthy weight were three times as likely to experience sudden cardiac death as women whose weight remained stable, no matter what their weight. The risk of death from cardiovascular disease was 66 percent greater in the normal-weight dieters compared with other women.

The observational study could not determine cause and effect, and studies on yo-yo dieting have had inconsistent results, Rasla said. More research, including studies of genetic alterations, insulin resistance and stress, might explain how weight cycling damages the heart, he said. — *Laura Beil*

### Heartburn drugs may raise stroke risk

Popular heartburn drugs called proton pump inhibitors — already under investigation for possible links to dementia, kidney and heart problems (*SN: 6/11/16, p. 8*) — have a new health concern to add to the list. An analysis of almost 250,000 medical records in Denmark has found an association with stroke.

Researchers from the Danish Heart Foundation in Copenhagen studied patients undergoing gastric endoscopy from 1997 to 2012. About 9,500 of all patients studied suffered from ischemic strokes, which occur when a blood clot blocks a blood vessel in the brain.

Taking a proton pump inhibitor was associated with a 21 percent higher risk of stroke, the researchers reported November 15. While those patients also tended to be older and sicker to start with, the level of risk was associated with dose. People taking the lowest doses (between 10 and 20 milligrams a day, depending on the drug) did not have a higher risk. At the highest doses, though, Prevacid (more than 60 mg/day) carried a 30 percent higher risk and Protonix (more than 80 mg/day) a 94 percent higher risk. For Prilosec and Nexium, stroke risk was within that range.

Proton pump inhibitors are valuable drugs, but people often take them for too long or without a clear reason, said lead author Thomas Sehested. — *Laura Beil*

MATTER & ENERGY

# Supersolids made from exotic matter

## Superfluid Bose-Einstein condensates given crystal structures

**BY EMILY CONOVER**

A mind-bogglingly strange state of matter may have finally made its appearance. Two teams of scientists report the creation of supersolids, which have a rigid crystalline structure like a solid but can simultaneously flow without friction like a superfluid.

Research teams from MIT and ETH Zurich both produced supersolids in an exotic form of matter known as a Bose-Einstein condensate. Reports of the work were published online at arXiv.org on October 26 (by the MIT group) and September 28 (by the Zurich group).

Bose-Einstein condensates form when a group of atoms, chilled to near absolute zero, huddle up into the same quantum state and behave like a single entity. The scientists nudged the condensate, which is already a superfluid, to simultaneously behave like a solid. To do so, both teams created regular density variations in the atoms — like the repeating crystal structure of a typical solid. That density variation stays put, even though the fluid can still flow.

The results may be the first supersolids ever created — at least by some definitions. "It's certainly the first case where you can unambiguously look at a system and say this is both a superfluid and a solid," says theoretical physicist Sarang Gopalakrishnan of the College of Staten Island of the City University of New York. But the systems are far from what physicists predicted when they first dreamed up the strange materials.

Scientists originally expected supersolids to appear in helium-4, an isotope of helium. Helium-4 can be chilled and pressurized to produce a superfluid or a solid. Supersolid helium would be a mixture of these two states. Claims of detecting supersolid helium-4, however, haven't held up to scrutiny (*SN Online: 10/12/12*). "Now we have to go to the artificial quantum matter," says theoretical physicist Nikolay Prokof'ev of the University of Massachusetts Amherst. Unlike helium-4, Bose-Einstein condensates can be precisely controlled with lasers and tuned to behave as scientists wish.

The two research groups formed their supersolids in different ways. By zapping a condensate with lasers, the MIT group induced an interaction that gave some of the atoms a shove. This motion caused an interference between the pushed and the motionless atoms that's similar to the complex patterns of ripples that can occur when waves of water meet. As a result, zebralike stripes — alternating high- and low-density regions — formed in the material, indicating it was a solid.

The ETH Zurich team used two optical cavities — sets of mirrors between which light bounces back and forth repeatedly — to make atoms interact and arrange themselves into a crystalline pattern, with atoms separated by an integer number of wavelengths of light.

Authors of the two studies declined to comment because the papers have been submitted to embargoed journals.

"Experimentally, of course, these are absolutely fantastic achievements," says Anatoly Kuklov, a theoretical physicist at the College of Staten Island. But, he notes, the particles in the supersolid Bose-Einstein condensates do not interact as strongly as particles would in supersolid helium-4.

The idea of a supersolid is so strange because superfluid and solid states compete, and in most materials, atoms are forced to choose one or the other. But in Bose-Einstein condensates, these two states can more easily live together in harmony, making the weird materials less counterintuitive than supersolid helium-4 would be.

Prokof'ev adds that "some people will say, 'OK, well, this does not qualify exactly for supersolid state,'" because the spacing of the density variations was set externally, rather than arising naturally. Still, he says, such supersolids are interesting as a strange and new type of material. ■

PROFESSOR BENEZETH MUTAYOBA/SOKOINE UNIV. OF AGRICULTURE, TANZANIA.

LIFE & EVOLUTION

## Most illegal ivory is less than 3 years old

Around 90 percent of ivory seized by law enforcement comes from African elephants that died less than three years before seizure, a study of ivory samples finds. The results confirm what many conservationists have suspected: Long-term stockpiles don't contribute much ivory to illegal trade, and poached ivory quickly ends up in illegal markets.

Thure Cerling of the University of Utah and colleagues analyzed 231 ivory pieces seized in 14 raids in Asia and Africa from 2002 to 2014 (including a 2002 raid in Singapore, shown). Radiocarbon dating of tusks pinpointed elephants' time of death.

Just one tested specimen came from an elephant that died more than six years earlier, the team reports online November 7 in the *Proceedings of the National Academy of Sciences*. In geographic trends, ivory from East Africa appeared on the market faster than ivory from a forested area of Central Africa. — *Helen Thompson*

LIFE & EVOLUTION

# Red squirrels harbor leprosy bacteria

## Microbes may have been lurking in British rodents for centuries

**BY LAUREL HAMERS**

Leprosy has been hiding out in red squirrels in Great Britain and Ireland, though the painful and disfiguring disease has rarely been transmitted between humans there since the Middle Ages.

The rodents have tested positive for leprosy-causing bacteria in several locations around the British Isles, researchers report in the Nov. 11 *Science*.

"It goes to show that once a disease has become extinct in humans, it could still exist in the environment if there was a suitable reservoir," says study coauthor Stewart Cole of the Swiss Federal Institute of Technology in Lausanne.

Until recently, leprosy, also known as Hansen's disease, was thought to be transmitted only between humans. But in 2011, a team of scientists that included Cole found the disease in armadillos in the southern United States (*SN: 5/21/11, p. 9*).

"One of the things we've never really understood about leprosy is how it can persist in populations at such low prevalence for such long periods of time," says Richard Truman, a microbiologist at the National Hansen's Disease Program in Baton Rouge, La., who wasn't part of the study. The new discovery might help explain this mystery.

The relatively high prevalence of leprosy bacteria found in British red squirrel populations is also surprising, Truman says. Cole and collaborators analyzed 110 red squirrel carcasses from Scotland, Ireland and two small English islands. All 13 of the visibly sick squirrels and 21 out of 97 seemingly healthy ones tested positive for the bacteria (either *Mycobacterium lepromatosis* or *Mycobacterium leprae*). Sick squirrels had skin lesions, patchy fur and nerve problems, similar to the symptoms seen in humans.

Red squirrels across the British Isles carry bacteria that cause leprosy. This one shows signs of the disfiguring disease on its ear and muzzle.

Squirrels' *M. leprae* strain is similar to the strain that made the rounds in medieval England, Cole says. That suggests the bacteria could have circulated in red squirrels for hundreds of years without changing very much (*SN: 7/13/13, p. 18*).

Up to 95 percent of people have some natural immunity to leprosy, Truman says. So the odds of catching it are slim. But squirrels carry other diseases too, so it's best to observe the creatures from a safe distance. ■

ATOM & COSMOS

# Swirls possible in infant cosmos

## Simulations suggest vortices arose in quark-gluon plasma

**BY EMILY CONOVER**

Complex swirls and vortices can appear in the souplike phase of matter that existed moments after the Big Bang. Computer simulations show that this substance, a quark-gluon plasma, can contain "the hottest smoke ring in nature," says Xin-Nian Wang of Lawrence Berkeley National Laboratory, coauthor of a paper in the Nov. 4 *Physical Review Letters*.

Wang and colleagues simulated collisions like those at the Relativistic Heavy Ion Collider at Brookhaven National Laboratory in Upton, N.Y., where gold ions are slammed together at nearly the speed of light. Such smashups produce an extremely hot, dense fluid, in which particles called quarks and gluons — the constituents of protons and neutrons — roam free. This quark-gluon plasma hits temperatures of trillions of degrees Celsius, hundreds of thousands of times hotter than the sun's core (*SN: 3/13/10, p. 8*).

Studying the whorls that appear in this quark-gluon plasma "is a truly new direction," says physicist Michael Lisa of Ohio State University. When scientists initially began investigating the plasma, they thought it would behave like a simple fireball, expanding rapidly outward. But in the aftermath of the simulated collisions, the quark-gluon plasma churned like a smoke ring, with spinning, doughnut-shaped regions. Pairs of whirlpool-like eddies appeared in the fluid as well. A similar effect can be seen if you drag your hand through a swimming pool, says Wang. Vortices, which rotate in opposite directions, are produced on either side. "This is exactly what we find is happening here in our simulation," Wang says.

These structures' appearance is "both surprising and not surprising," says cosmologist Kevork Abazajian of the University of California, Irvine. "We don't know what to actually expect." The result may have implications for the quark-gluon plasma in the early universe, he says, but there are notable differences between that plasma and the plasma produced in ion collisions. The young universe is thought to have been relatively uniform; quark-gluon plasma made in collisions can be irregular. But if swirls did form in the early universe, says Abazajian, "something novel or something very different could actually happen," such as black hole formation early in the universe's history.

To observe eddies in a real quark-gluon plasma, scientists could study particles produced in ion collisions. These particles have a property called spin, which tends to trace the vorticity of the fluid. Scientists can detect the influence of this spin by observing decays of certain particles and measuring the angles at which their decay products are emitted to determine the vorticity of the fluid. Though swirls have not yet been seen, experiments to search for them are under way. ■

CATHERINE CLARK

BODY & BRAIN

# Prionlike protein stores memories

## Fruit fly study offers clues to mechanism for remembering

**BY LAURA SANDERS**

A protein that can switch shapes and accumulate inside brain cells helps fruit flies form and retrieve memories, a new study finds.

Such shape-shifting is the hallmark of prions — proteins that can alternate between two forms and aggregate under certain conditions. In fruit flies' brain cells, clumps of the prionlike protein called Orb2 store long-lasting memories, report scientists from the Stowers Institute for Medical Research in Kansas City, Mo. Figuring out how the brain forms and calls up memories may help scientists devise ways to restore that process in people with diseases such as Alzheimer's.

The new finding, described online November 3 in *Current Biology*, is "absolutely superb," says neuroscientist Eric Kandel of Columbia University. "It fills in a lot of missing pieces."

People possess a version of the Orb2 protein called CPEB, suggesting that memory might work similarly in people, Kandel says. "We can't be sure, but it's very suggestive."

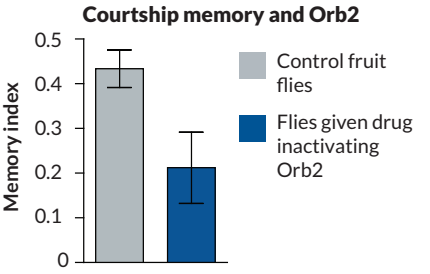
When neuroscientist Kausik Si and colleagues used a drug to trigger a genetic trick that inactivated Orb2, male flies were bad at remembering rejection. These males wooed a nonreceptive female long past when they should have learned that courtship was futile.

Si and colleagues found a different protein, JJJ2, that helps Orb2 switch shapes, a change that then allows Orb2 to aggregate. When the researchers boosted levels of JJJ2, a situation that led to more Orb2 accumulation, flies had sharper memories. Usually, flies need about six hours of training to learn that an unreceptive female really doesn't want to mate. But after a JJJ2 boost, flies learned that courtship was futile in only two hours. This memory lasted for days.

Kandel, whose work has turned up evidence for CPEB's role in memory in sea slugs and mice, says that the study makes the concept that prions can stabilize memories "quite definitive now."

JJJ2 didn't lead to supersmart flies that could learn everything quickly, though. The boost came only for memories that would have been formed anyway, Si says. The change "lowered the threshold for memory formation." But, he says, "it can only [affect] memory when the conditions are right to produce a memory."

The Orb2 study examined just long-term memory. "There could be other biochemical processes for other types of memory," such as immune cells' memories of former threats, Si says. Still, it's possible that protein accumulation is a fundamental way that memory works. ■




**Can't remember** Male flies fed a drug (blue) that interfered with the protein Orb2 were worse at remembering not to woo an unreceptive female than flies that didn't get the drug (gray). A higher memory index indicates better memory. SOURCE: L. LI *ET AL/CURRENT BIOLOGY* 2016

BODY & BRAIN

# Eyes offer peek at brain's timekeepers

## In monkeys, pupil size is related to perception of duration

**BY LAURA SANDERS**

The eyes may reveal whether the brain's internal stopwatch runs fast or slow. Pupil size predicted whether a monkey would over- or underestimate a second, researchers report in the Nov. 2 *Journal of Neuroscience*.

Scientists knew that pupils get bigger when a person is paying attention. They also knew that paying attention can influence how people perceive the passage of time. Using monkeys, the new study links pupil size and timing directly. "What they've done here is connect those dots," says Thalia Wheatley, a neuroscientist at Dartmouth College. More generally, the study shows how the eyes are windows into how the brain operates.

Masaki Tanaka, a neuroscientist at Hokkaido University School of Medicine in Japan, and colleagues trained three macaques to look at a spot on a computer screen after precisely one second had elapsed. The monkeys had to rely on themselves to count the milliseconds. Just before each trial, the researchers measured pupil diameters.

When the monkeys underestimated a second by looking too soon, their pupil sizes were slightly larger than when the monkeys overestimated a second. So when pupils were large, the monkeys felt time zoom by faster than it really was. When pupils were small, time seemed slower.

The differences in pupil size were subtle, but Tanaka and colleagues say the changes are meaningful. Pupils, the results suggest, offer a readout of the brain as it keeps track of time.

This pupil readout may reflect a specific type of signaling in the brain. As a chemical messenger called noradrenaline puts the brain into a heightened state of alertness, pupils get bigger, research has shown. That link is why this study makes sense, Wheatley says. In some cases, attention makes time fly, a distortion that would lead a monkey to think a second has elapsed sooner than it has. The opposite is also true. When the brain is sluggish or not paying attention, time ticks more slowly and seconds stretch out.

Tanaka says the study may motivate further research into how brain cells actually make this split-second calculation (*SN: 7/25/15, p. 20*). ■

# Gamma rays linked to fast radio burst

## Energetic photons may be clues to cause of mysterious signals

**BY CHRISTOPHER CROCKETT**

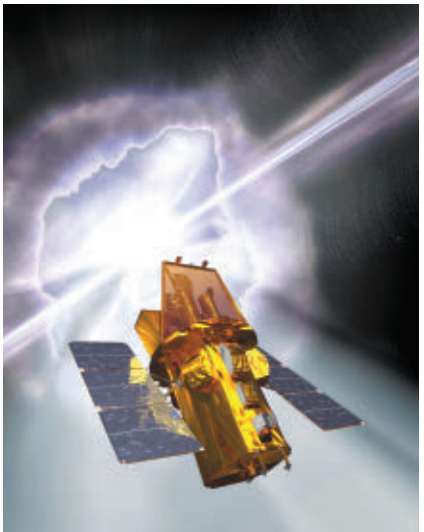
Mysterious flashes of radio waves from deep space keep coming, but they are just as mysterious as ever.

Gamma rays might have accompanied one of these eruptions, researchers report in the Nov. 20 *Astrophysical Journal Letters*. This is the first time high-energy photons have been associated with these blasts of radio energy, known as fast radio bursts. If the gamma rays did come from the same place as the radio waves, then the underlying source could be roughly 1 billion times as energetic as thought.

Another burst, meanwhile, takes the record for brightest blast. It was bright enough to reveal details about the magnetic field between galaxies, astronomers report online November 17 in *Science*.

Fast radio bursts, or FRBs, have intrigued astronomers since the first one was reported in 2007 (*SN: 8/9/14, p. 22*). Since then, astronomers have discovered 18 in total. In most cases, a blip of radio waves lasting just a few milliseconds appears in the sky and is never seen again. Only one so far is known to repeat (*SN: 4/2/16, p. 12*). Most seem to originate in remote galaxies, possibly billions of light-years away. Until now, no one has detected any other frequency of electromagnetic radiation besides radio waves coming from these cosmic beacons.

NASA's Swift satellite (illustrated) detected gamma rays that might illuminate the origins of mysterious cosmic radio bursts.



SPECTRUM AND NASA E/PO, SONOMA STATE UNIV., AURORE SIMONNET

A flash of gamma rays appeared at about the same time and from the same direction as a radio burst detected in 2013, James DeLaunay, a physics graduate student at Penn State, and colleagues report. They pored over old data from the Swift observatory, a NASA satellite launched in 2004, to see if it recorded any surges of gamma rays that might coincide with known radio bursts.

"Gamma rays associated with an FRB would be an incredibly important thing to find," says Sarah Burke Spolaor, an astrophysicist at the National Radio Astronomy Observatory in Socorro, N.M. But she urges caution. "We don't have a good inkling of where a specific burst comes from." That leaves room for other types of eruptions to occur in the vicinity just by chance. DeLaunay and collaborators calculate that the odds of that are low, about one in 800. But several researchers are taking a wait-and-see attitude before feeling more confident that the gamma rays and FRB are linked.

"It's tantalizing, but a lot more would need to be found to be convincing," says Jason Hessels, an astrophysicist at the Netherlands Institute for Radio Astronomy in Dwingeloo.

If the same source emits both the radio waves and gamma rays, that could rule out a couple of proposals for the causes of the eruptions. Powerful radio hiccups from pulsars, the rapidly spinning cores of dead stars, are one candidate that wouldn't make the cut, because they aren't known to generate gamma rays.

Collisions between two neutron stars, or between a neutron star and a black hole, look promising, says Derek Fox, an astrophysicist at Penn State and a coauthor of the study. The energy output and duration of the gamma-ray burst are a good match with what's expected for these smashups, he says, though it's not clear whether they happen often enough to account for the thousands of FRBs that astronomers suspect go off every day.

No one story neatly fits all the data. "I think there are at least two populations," says Fox. Perhaps some FRBs repeat, while others do not; some belch out gamma rays, others do not. There might be no one type of event that creates all FRBs, but rather a multitude.

That idea is tentative as well. "It's way too early to say if there are multiple populations," says Laura Spitler, an astrophysicist at the Max Planck Institute for Radio Astronomy in Bonn, Germany. A grab bag of cosmic calamities is plausible. But other astronomical events exhibit enormous diversity; all FRBs could also have just one type of trigger. "The data we have now isn't sufficient to land on one side or the other," Spitler says.

A more recent FRB, detected at Australia's Parkes radio telescope in 2015, shows some of that diversity — and demonstrates how FRBs can be used as cosmological tools. The brief blast of radio waves from at least 1.6 billion light-years away is about four times as intense as the previous record holder. The signal's vigor could be a quirk of the outburst's underlying cause, or could mean this burst was unusually close to our galaxy — or both.

"What's really exciting most about it is not just that it's bright," says Vikram Ravi, a Caltech astronomer and lead author of the study in *Science*, "but really because of what we hope to use FRBs for." This FRB was bright enough for Ravi and colleagues, including Burke Spolaor, to deduce the strength of the magnetic field between galaxies. They found that, on average, the magnetic field is feeble, less than 21 nanogauss (or about one 10-millionth as strong as Earth's magnetic field). That's in line with astronomers' theories about the strength of intergalactic magnetism.

"It's not telling us anything that's unexpected," says Duncan Lorimer, an astrophysicist at West Virginia University in Morgantown who reported the first known FRB in 2007. But it shows that FRBs can reveal more about intergalactic space, which is notoriously difficult to study. "It's one thing to say we expect the magnetic field to be weak, but it's another thing to actually measure it," he adds. ■

BODY & BRAIN

# Sensory overload hurts young brains

## Flashing lights and noise caused behavioral problems in mice

**BY LAURA SANDERS**

Mice raised in cages bombarded with glowing lights and sounds have profound brain abnormalities and behavioral trouble. Hours of daily stimulation led to behaviors reminiscent of attention-deficit/hyperactivity disorder, scientists reported November 14.

Certain kinds of sensory stimulation, such as sights and sounds, are known to help the brain develop correctly. But scientists from Seattle Children's Research Institute wondered whether too much stimulation or stimulation of the wrong sort could have negative effects on the growing brain.

To mimic extreme screen exposure, mice were blasted with flashing lights and TV audio for six hours a day. The cacophony began when the mice were 10 days old and lasted for six weeks. After the end of the ordeal, scientists examined the mice's brains.

"We found dramatic changes everywhere in the brain," said study coauthor Jan-Marino Ramirez.

Compared with nonstimulated mice, mice that had been stimulated had fewer newborn nerve cells in the hippocampus, a brain structure important for learning and memory, Ramirez said. The stimulation also made certain nerve cells more active in general.

Stimulated mice also displayed behaviors similar to some associated with ADHD in children. These mice were noticeably more active and had trouble remembering whether they had encountered an object. The mice also seemed more inclined to take risks, venturing into open areas that mice normally shy away from, for instance.

Some of these results have been reported previously by the Seattle researchers, who have now replicated the findings in a different group of mice. Ramirez and colleagues are extending the work by looking for more detailed behavioral changes.

For instance, preliminary tests have revealed that the overstimulated mice are impatient and have trouble waiting for rewards. When given a choice between a long wait for a reward of four food pellets and a short wait for one pellet, stimulated mice were more likely to go for the instant gratification than nonstimulated mice, particularly as wait times increased.

Overstimulation didn't have the same effects on adult mice, a result that suggests the stimulation had a big influence on the developing — but not fully formed — brain.

If massive amounts of audio and visual stimulation do harm the growing brain, parents need to ponder how their children should interact with screens. So far, though, the research is too preliminary to change guidelines (*SN Online: 10/23/16*).

"We are not in a position where we can give parents advice," said Gina Turrigiano, a neuroscientist at Brandeis University in Waltham, Mass. The results are from mice, not children. "There are always issues in translating research from mice to people," said Turrigiano.

What's more, early sensory input may not affect all children the same way. "Each kid will respond very, very differently," Turrigiano said. Those different responses might be behind why some children are more vulnerable to ADHD.

There's still much scientists don't understand about how sensory input early in life wires the brain. It's possible that what seems like excessive sensory stimulation early in life might actually be a good thing for some children, sculpting brains in a way that makes them better at interacting with the fast-paced technological world, said Leah Krubitzer of the University of California, Davis.

"This overstimulation might be adaptive," she said. "The benefits may outweigh the deficits." ■

BODY & BRAIN

# Parkinson's may begin in the gut

## In mice, proteins linked to the disease moved up to the brain

**BY LAURA SANDERS**

Over the course of months, clumps of a protein implicated in Parkinson's disease can travel from the gut into the brains of mice, scientists have found.

The results, reported November 14, suggest that in some cases, Parkinson's may get its start in the gut. That's an intriguing concept, said neuroscientist John Cryan of University College Cork in Ireland. The new study "shows how important gut health can be for brain health and behavior."

Collin Challis of Caltech and colleagues injected clumps of synthetic alpha-synuclein, a protein known to accumulate in the brains of people with Parkinson's, into mice's stomachs and intestines. The researchers then tracked alpha-synuclein with a technique called CLARITY, which makes parts of the mice's bodies transparent.

Seven days after the injections, researchers saw alpha-synuclein clumps in the gut. Levels there peaked 21 days after the injections. These weren't the same alpha-synuclein aggregates that were injected, though. These were new clumps, formed from naturally occurring alpha-synuclein, that researchers believe were coaxed into forming by the synthetic versions in their midst.

Also 21 days after the injections, alpha-synuclein clumps seemed to have spread to a part of the brain stem containing cells that make up the vagus nerve, a neural highway that connects the gut to the brain (*SN: 11/28/15, p. 18*). Sixty days after the injections, alpha-synuclein had accumulated in the midbrain, a region packed with nerve cells that make the chemical messenger dopamine. These cells die in people with Parkinson's, a progressive brain disorder that affects movement.

Within the brain, alpha-synuclein spreads thanks in part to cells called

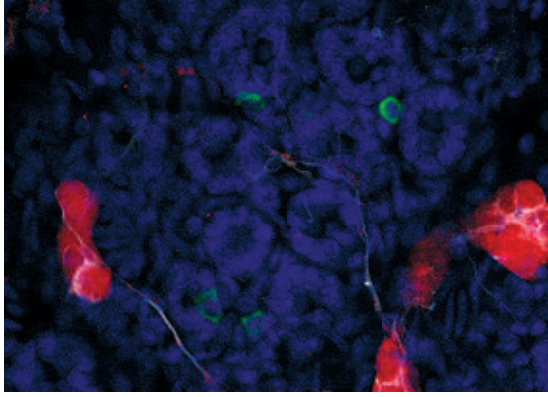
astrocytes, a second study suggests. Experiments in dishes showed that astrocytes can store and spread alpha-synuclein among cells. Jinar Rostami of Uppsala University in Sweden presented that work at a news briefing November 14.

The gradual accumulation and spread of alpha-synuclein caused trouble in the mice. Seven days after the injections, the mice produced more stool than usual. Sixty and 90 days after the injections — after clumps of alpha-synuclein had reached the brain — the mice performed worse on some physical tests, including getting a sticker off their face and flipping around to shinny down a pole headfirst. The mice resembled other mice that have mutations that cause Parkinson's-like symptoms, Challis said.

An earlier study found that clumps of alpha-synuclein can move from the gut to the brain stem in rats, but those experiments looked at shorter timescales, Challis said. And previous work monitored the injected alpha-synuclein, not the alpha-synuclein clumps that the mice produced themselves.

These new alpha-synuclein results and others have prompted scientists to start looking outside of the brain for the beginning stages of Parkinson's, said Alice Chen-Plotkin, a clinician and Parkinson's researcher at the Hospital of the University of Pennsylvania. "Increasingly, people are wondering if it starts earlier."

Some evidence suggests that the gut is a good place to look. People with Parkinson's often suffer from gut problems such as constipation. In 2015, scientists reported that a group of Danish people who had their vagus nerves severed were less likely to develop Parkinson's. Cut alpha-synuclein's transit route from the gut to the brain, and the disease is less likely to take hold, that study hints.



Clumps of alpha-synuclein protein, implicated in Parkinson's, can move from the gut to the brain. Clumps (green) in this mouse gut mingle with nerve cells (red) and astrocytes (white).

It's not clear why alpha-synuclein accumulates in the gut in the first place. Bacteria may produce compounds called curli that prompt alpha-synuclein to aggregate, a recent study suggests. Pesticides, acid reflux and inflammation are other possible culprits that could somehow increase alpha-synuclein clumps in the gut, Challis said. ■

COLLIN CHALLIS/GRADINARU GROUP/CALTECH

MEETING NOTES

## Despite Alzheimer's plaques, some seniors remain mentally fit

A small number of people maintain razor-sharp memories into their 90s, despite having brains chock-full of the plaques and tangles linked to Alzheimer's disease. Researchers suspect that these people's brains are somehow impervious to the usual devastation thought to be caused by those plaques and tangles.

Researchers studied the brains of people 90 years old or older who had excellent memories, performing as well as people in their 50s and 60s on some tests. Postmortem brain tissue from eight such people revealed a range of Alzheimer's features. Two participants had remarkably clean brains with few signs of amyloid-beta plaques and tangles of tau protein. Four participants had middling levels.

Surprisingly, the other two samples were packed with enough plaques and tangles to qualify those people for an Alzheimer's diagnosis based on their brains. "These people, for all practical purposes, should be demented," study coauthor Changiz Geula of Northwestern University's medical school said November 15 in a news briefing.

Further tests revealed that even in the midst of these Alzheimer's hallmarks, nerve cells survived in people with strong memories. Those people had more healthy-looking nerve cells than people with dementia and similar plaque and tangle levels. The researchers don't know how these mentally sharp people avoid the ravages usually accompanying plaques and tangles. "What's surprising is this segment of people does exist," Geula said. "We have to find out why." — *Laura Sanders*

## Infant brains have powerful reactions to fearful faces

Babies as young as 5 months old possess networks of brain cell activity that react to facial emotions, especially fear, a new study finds.

"Networks for recognizing facial expressions are in place shortly after birth," Catherine Stamoulis of Harvard Medical School said November 13 during a news conference. "This work … is the first evidence that networks that are involved in a function that is critical to survival, such as the recognition of facial expressions, come online very early in life."

Stamoulis and colleagues analyzed a database of brain electrical activity collected from 58 infants as they aged from 5 months to 3 years. Brain activity was measured as they viewed pictures of female faces expressing happiness, anger or fear. Computer models of the brain activity showed that networks responding to fear were activated much more dramatically than those for happy or angry faces, even in the youngest infants.

As babies grew older, their brain networks responding to facial emotions became less complex as redundant nerve cell connections were pruned. But the fear network remained more complex than the others, and response to fearful faces remained elevated over time. Understanding the brain circuitry involved in responding to emotional facial expressions could have implications for research on developmental disorders, Stamoulis said. — *Tom Siegfried*

BODY & BRAIN

# Heart problems tied to mom's diet

## Baboon study reveals risks of malnutrition during pregnancy

**BY LAURA BEIL**

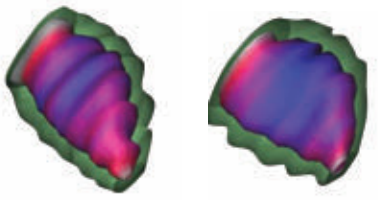
Mothers who don't eat enough during pregnancy could give birth to babies with long-lasting heart problems. The results from a new study in primates add to accumulating evidence that a mother's nutrition has more bearing on her child's health than previously thought.

"We pass more biological milestones during [fetal] development than we will ever pass again in our entire lives," says Peter Nathanielsz, coauthor of the study published online November 6 in the *Journal of Physiology*. And during those crucial nine months, calorie intake at the extremes — too many or too few — appears to have a lifelong influence on newborn weight, future metabolism and chronic health problems (*SN: 1/23/16, p. 22*).

One landmark investigation found that people born in the Dutch Hunger Winter during World War II suffered from an elevated risk of heart disease and other health concerns, with some risks even affecting the next two generations. But studies of human populations are complicated. It's hard to account for the role of stress, behavior or environmental exposures. So Nathanielsz, of the University of Wyoming in Laramie, and colleagues studied baboons, close relatives of humans.

Sixteen pregnant baboons were fed their normal amount of chow, while 16 others received 30 percent less during pregnancy, a reduction researchers characterize as "moderate." All other living conditions were the same. The researchers then compared offspring of the well-fed mothers with the offspring of undernourished mothers.

Infants of the underfed mothers were born small but nonetheless by young adulthood caught up in body weight to the offspring of the well-fed mothers. However, those with underfed mothers had more fibrous, abnormally shaped heart muscle, the researchers report. A normal heart is roughly an upside-down pyramid. Underfed offspring had more rounded, thinner-walled hearts that were not as efficient at pumping blood, with an average output about 20 percent lower.



**Normal diet** **Reduced calorie diet**

The heart of a baboon born to a mother moderately undernourished during pregnancy has a spherical shape (right, reconstruction based on MRI scans). It pumps blood less efficiently than the pyramid-shaped hearts of offspring with well-fed mothers (left).

Offspring of the undernourished also had hearts that appeared to age faster. By age 5, the human equivalent of almost 25, many heart functions more closely resembled those of primates about three times as old.

Such experiments can show cause and effect — something that human studies can't do, says Susan Ozanne, a developmental endocrinologist at the University of Cambridge. As a result, they provide

GENES & CELLS

# Protein mobs selectively kill brain cells

## Artificial amyloids give insight into neurodegenerative diseases

**BY TINA HESMAN SAEY**

Joining a gang doesn't necessarily make a protein a killer, a new study suggests. Protein clumping gets dangerous only under certain circumstances.

A normally innocuous protein can be engineered to clump into fibers similar to those formed by proteins involved in Alzheimer's, Parkinson's and brain-wasting prion diseases such as Creutzfeldt-Jakob disease, researchers report in the Nov. 11 *Science*. Cells that rely on the protein's normal function for survival die when the proteins glom together. But cells that don't need the protein are unharmed, the researchers discovered. The finding may shed light on why clumping proteins that lead to degenerative brain diseases kill some cells but leave others untouched.

Clumpy proteins such as prions and amyloids have been implicated in many nerve cell–killing diseases. Such proteins are twisted-up forms of normal proteins that can make other normal copies of the protein go rogue, too. The contorted proteins band together and can form large clusters or plaques and kill brain cells.

Scientists don't fully know why these mobs sometimes resort to violence or how they kill cells. That's partly because researchers aren't sure what jobs, if any, many of the proteins normally perform.

A team led by biophysicists Frederic Rousseau and Joost Schymkowitz of Catholic University Leuven in Belgium came up with a new way to dissect the problem. They started with a protein for which they already knew the function and engineered it to clump. That protein, vascular endothelial growth factor receptor 2, or VEGFR2, is involved in blood vessel growth. Rousseau and colleagues isolated a portion of the protein that causes it to cluster with other proteins to create what the researchers call an artificial amyloid.

Masses of the protein fragment, nicknamed vascin, aggregated with and blocked normal activity of VEGFR2. When the researchers added vascin to human umbilical vein cells grown in a lab dish, the cells died because VEGFR2 no longer transmitted hormone signals the cells need to survive. But embryonic kidney cells and bone cancer cells remained healthy. Those results suggest that some forms of clumpy proteins may not be generically toxic to cells, says biophysicist Priyanka Narayan of

P. NATHANIELSZ, GEOFFREY CLARKE

strong evidence about the effects of maternal nutrition. Studies in rodents have produced similar findings about the long-term effects of maternal nutrition on heart health. "When you validate those in multiple species, it shows you you're looking at a fundamentally conserved mechanism," Ozanne says.

The next step, she says, is to learn whether diet and exercise after birth can make up for poor nutrition during development. Doctors also don't know whether there is a window of time during childhood for intervention, or a longer period to counteract any effects, she says.

Much attention on maternal nutrition has focused on the obesity epidemic, Nathanielsz says, but undernutrition remains a public health challenge throughout the world, even in developed countries. According to the U.S. Department of Agriculture, approximately 13 percent of American households in 2015 reported food insecurity, or uncertainty about having enough money for food. "The number of people with food insecurity is very high," Nathanielsz says. "It would be sad if we discounted this problem." ■

the Whitehead Institute for Biomedical Research in Cambridge, Mass. Instead, rogue clumpy proteins may target specific proteins and kill only cells that rely on those proteins for survival.

Those findings may indicate that prion and amyloid proteins, such as Alzheimer's nerve-killing amyloid-beta, normally play important roles in some brain cells. Those cells would be vulnerable to attack from the clumpy proteins.

The newly engineered protein may open new ways to inactivate specific proteins to fight cancer and other diseases, says Salvador Ventura, a biophysicist at the Autonomous University of Barcelona. Synthetic amyloids of overactive cancer proteins could gang up and shut down the problem protein, killing the tumor.

Artificial amyloids might also help screen for potential drugs for anticlumping activity that could help combat brain-degenerating diseases, Rousseau says. ■

EARTH & ENVIRONMENT

# Arctic summer may be iceless by 2050

## Researchers calculate each person's contribution to loss

**BY THOMAS SUMNER**

The average American's carbon dioxide emissions are responsible for shrinking Arctic sea ice by nearly 50 square meters each year.

That's the implication of a new study that finds that each additional metric ton of $CO_2$ released results in a 3-square-meter loss of Arctic sea ice cover at summer's end.

"For the first time now, it is possible to grasp how each one of us contributes to tangible consequences for the global climate system," says Dirk Notz, a climate scientist at the Max Planck Institute for Meteorology in Hamburg.

Globally, humans are responsible for the release of some 36 billion metric tons of $CO_2$ each year. With another trillion metric tons released, the Arctic Ocean will have a completely iceless summer — possibly the first in 125,000 years, Notz and Julienne Stroeve of University College London estimate in the Nov. 11 *Science*. That threshold could be crossed before 2050, the researchers report. Many studies have projected that this ice would stick around for years longer.

Dwindling ice at the top of the world threatens Arctic species, can spread pollution (*SN: 1/23/16, p. 9*) and could open the region to transpolar shipping. In 2012, Arctic sea ice hit a record low since satellite observations began: just 3.41 million square kilometers, far below the 1981–2010 average minimum of 6.22 million square kilometers. How quickly the ice will continue to disappear has been unclear.

| Country | Carbon dioxide emissions per person (in metric tons) | Arctic sea ice loss per person (in square meters) |
|---|---|---|
| Qatar | 40.5 | 121.5 |
| United States | 16.4 | 49.2 |
| Australia | 16.3 | 48.9 |
| China | 7.6 | 22.8 |
| United Kingdom | 7.1 | 21.3 |
| Uganda | 0.1 | 0.3 |

**Meltdown** A country's annual per capita impact on Arctic sea ice loss, new research shows, is directly related to its per capita carbon dioxide emissions, which are largely the result of fossil fuel burning. SOURCE: OAK RIDGE NATIONAL LABORATORY

Notz and Stroeve analyzed records of Arctic sea surface temperature and minimum sea ice extent since 1953. The average extent of September sea ice declined in lockstep with the rising total amount of $CO_2$ released from human sources.

This simple relationship between emissions and ice loss stems from one similarly straightforward mechanism, the researchers propose. As $CO_2$ concentrates in the atmosphere, it strengthens the greenhouse effect, sending some heat back to Earth that would otherwise escape into space. This increases the amount of ice-warming infrared radiation hitting the Arctic, causing the outermost edge of the sea ice to retreat northward, reducing total ice coverage.

Climate simulations underestimate this effect and don't accurately re-create the sensitivity of Arctic sea ice to rising $CO_2$ levels, the researchers argue. Other factors linked to sea ice loss, such as changes in ocean heat flowing from the Atlantic Ocean and in the Arctic's reflectiveness, were minor over the studied period compared with the increased radiative heating, Notz says.

Downplaying ocean heating's role is a mistake, says oceanographer Rong Zhang of the National Oceanic and Atmospheric Administration's Geophysical Fluid Dynamics Laboratory in Princeton, N.J. The area of sea ice coverage peaks in winter, when little light shines on the Arctic and the greenhouse effect is less important. Like the minimum, the maximum extent of sea ice has also declined. More observations are needed to determine whether warming from below or above the ice plays a larger role, Zhang says. ■

Audio recordings from the Arctic suggest that narwhals take directional sonar to the extreme.

LIFE & EVOLUTION

## Narwhals are really, really good at echolocation

Narwhals use highly targeted beams of sound to scan their environment for threats and food. In fact, the so-called unicorns of the sea (for their iconic head tusks) may produce the most refined sonar of any living animal.

An international team of researchers set up 16 underwater microphones to eavesdrop on narwhal click vocalizations at 11 pack ice sites in Greenland's Baffin Bay in 2013. The recordings show that narwhal clicks are extremely intense and directional. Narwhals can widen and narrow the beam of sound to find prey over long and short distances. It's the most targeted sonar signal measured in a living species, the researchers report November 9 in *PLOS ONE*.

The sound beams are asymmetric, narrowing on top. That minimizes noise clutter from echoes bouncing off the sea surface or pack ice, the researchers say. Narwhals also scan vertically as they dive, which could help them find patches of open water where they can surface and breathe amid sea ice cover. All this means that narwhals employ sophisticated sonar.

The audio data could help researchers tell the difference between narwhal vocalizations and those of neighboring beluga whales. It also provides a baseline for assessing the potential impact of noise pollution from increases in shipping traffic made possible by sea ice loss. *— Helen Thompson*

BODY & BRAIN

## Antibody protects against Zika virus in tests in mice

The battle against Zika may have some new firepower. A single dose of a human antibody called ZIKV-117 can shield mouse fetuses from the virus's damaging effects, researchers report online November 7 in *Nature*.

In humans, Zika virus infection during pregnancy has been linked to a suite of birth defects including a condition known as microcephaly, which leaves babies with shrunken heads and brains (*SN: 4/2/16, p. 26*). It's not yet clear whether a new treatment based on the antibody would work in humans (or even in monkeys). But if it does, ZIKV-117 could potentially offer pregnant women a way to defend themselves — and their babies — from a virus that tore through Brazil and has now encroached upon the United States. *— Meghan Rosen*

EARTH & ENVIRONMENT

## 2015's extreme heat could soon be new normal, simulations suggest

The sweltering heat that smashed temperature records in 2015 will soon be par for the course.

Depending on how much more carbon dioxide humans dump into the atmosphere, 2015 could become the "new normal" for global temperatures as soon as the 2020s, researchers estimate online November 4 in the *Bulletin of the American Meteorological Society*. Even if there's a sharp reduction in $CO_2$ emissions, the record-setting year (*SN: 2/20/16, p. 13*) will seem typical by 2040.

Those predictions are based on defining "new normal" — previously an informal term — as a point in time when at least half of the following 20 years surpass the record global average temperature. Climate scientist Sophie Lewis of Australian National University in Canberra and colleagues applied their new definition to several simulations of future climate.

When 2015's record heat is the new normal, extremely hot years will be beyond anything society has encountered, the researchers predict. That extreme heat could lead to more deadly heat waves (*SN: 9/3/16, p. 5*), wildfires and other climate-related disasters. *— Thomas Sumner*

EARTH & ENVIRONMENT

## Ocean plastic emits chemical that may trick seabirds into eating trash

Plastic smells like supper for some seabirds. When the ubiquitous material ends up in the ocean, it gives off a chemical that petrels, prions and shearwaters often use to locate food, researchers report November 9 in *Science Advances*. That might lead the birds to ingest harmful junk instead of a real meal.

Researchers at the University of California, Davis let small beads of three common plastics linger off the coast of California. After a few weeks, the once-clean plastic accumulated grit, grime and bacteria that gave off an odiferous gas called dimethyl sulfide (*SN: 2/20/16, p. 20*). Phytoplankton give off the same gas, and certain seabirds use the odor as a cue that dinner is nearby. Birds that rely more heavily on dimethyl sulfide as a beacon for a nearby meal are more likely to ingest plastic than birds that don't, the team found. Other marine animals that use the cue could also be fooled. *— Laurel Hamers*

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# GIVE YOUR SCIENCE LOVER

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The Dragonfly telescope (shown) in New Mexico has triggered a hunt for dim galaxies in our cosmic neighborhood.

P. VAN DOKKUM

# Dark Galaxies

## Astronomers detect a plethora of star-starved giants

**By Christopher Crockett**

Not all galaxies sparkle with stars. Galaxies as wide as the Milky Way but bereft of starlight are scattered throughout our cosmic neighborhood. Unlike Andromeda and other well-known galaxies, these dark beasts have no grand spirals of stars and gas wrapped around a glowing core, nor are they radiant balls of densely packed stars. Instead, researchers find just a wisp of starlight from a tenuous blob.

"If you took the Milky Way but threw away about 99 percent of the stars, that's what you'd get," says Roberto Abraham, an astrophysicist at the University of Toronto.

How these dark galaxies form is unclear. They could be a whole new type of galaxy that challenges ideas about the birth of galaxies. Or they might be outliers of already familiar galaxies, black sheep shaped by their environment. Wherever they come from, dark galaxies appear to be ubiquitous. Once astronomers reported the first batch in early 2015 — which told them what to look for — they started picking out dark denizens in many nearby clusters of galaxies. "We've gone from none to suddenly over a thousand," Abraham says. "It's been remarkable."

This haul of ghostly galaxies is puzzling on many fronts. Any galaxy the size of the Milky Way should have no trouble creating lots of stars. But it's still unclear how heavy the dark galaxies are. Perhaps these shadowy entities are failed galaxies, as massive as our own but mysteriously prevented from giving birth to a vast stellar family. Or despite being as wide as the Milky Way, they could be relative lightweights stretched thin by internal or external forces.

Either way, with so few stars, dark galaxies must have enormous deposits of unseen matter to resist being pulled apart by the gravity of other galaxies.

Astronomers can't resist a good cosmic mystery. With detections of these galactic oddballs piling up, there is a push to figure out just how many of these things are out there and where they're hiding. "There are more questions than answers," says Remco van der Burg, an astrophysicist at CEA Saclay in France. Cracking the code of dark galaxies could provide insight into how all galaxies, including the Milky Way, form and evolve.

### Compound eye on the sky

Telescopes designed to detect faint objects have revealed the presence of many sizable but near-empty galaxies — officially known as

"ultradiffuse galaxies." The deluge of discoveries started in New Mexico, with a telescope that looks more like a honeycomb than a traditional observatory. Sitting in a park about 110 kilometers southwest of Roswell (a city that has turned extraterrestrials into a tourism industry), the Dragonfly telescope consists of 48 telephoto lenses; it started with three in 2013 and continues to grow. The lenses are divided evenly among two steerable racks, and each lens is hooked up to its own camera. Partly inspired by the compound eye found in dragonflies and other insects, this relatively small scope has revealed dim galaxies missed by other observatories.

The general rule for telescopes is that bigger is better. A large mirror or lens can collect more light and therefore see fainter objects. But even the biggest telescopes have a limitation: unwanted light. Every surface in a telescope is an opportunity for light coming in from any direction to reflect onto the image. The scattered light shows up as dim blobs, or "ghosts," that can wash out faint detail in pictures of space or even mimic very faint galaxies.

Large dark galaxies look a lot like these ghosts, and so went unnoticed. But Dragonfly was designed to keep these splashes of light in check. Unlike most conventional professional telescopes, it has no mirrors. Precision antireflection coatings on the lenses keep scattered light to a minimum. And having multiple cameras pointed at the same part of the sky helps distinguish blobs of light bouncing around in the telescope from blobs that actually sit in deep space. If the same blob shows up in every camera, it's probably real.

"It's a very clever idea, very brilliant," says astronomer Jin Koda of Stony Brook University in New York. "Dragonfly made us realize that there is a chance to find a new population of galaxies beyond the boundary of what we know so far."

In spring 2014, researchers pointed Dragonfly at the well-studied Coma cluster, a conglomeration of thousands of galaxies. At a distance of about 340 million light-years, Coma is a close, densely packed collection of galaxies and a rich hunting ground for astronomers. A team led by Abraham and astronomer Pieter van Dokkum of Yale University was looking at the edges of galaxies for far-flung stars and stellar streams, evidence of the carnage left behind after small galaxies collided to build larger ones.

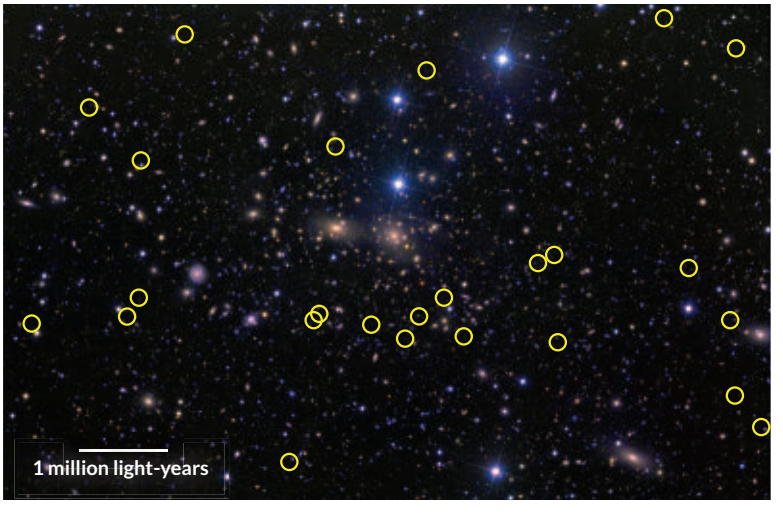
They were not expecting to find dozens of galaxies hiding in plain sight. "People have been studying Coma for 80 years," Abraham says. "How could we find anything new there?" And yet, scattered throughout the cluster appeared 47 dark galaxies, many of them comparable in size to the Milky Way — tens of thousands to hundreds of thousands of light-years across (*SN: 12/13/14, p. 9*). This was perplexing. A galaxy that big should have no problem forming lots of stars, van Dokkum and colleagues noted in September in *Astrophysical Journal Letters*.

## Hidden strength

Even more surprising, says Abraham, is that those galaxies survive in Coma, a cluster crowded with galactic bullies. A galaxy's own gravity holds it together, but gravity from neighboring galaxies can pull hard enough to tear apart a smaller one. To create sufficient gravity to survive, a galaxy needs mass in the form of stars, gas and other cosmic matter. In a place like Coma, a galaxy needs to be fairly massive or compact. But with so few stars (and presumably so little mass) spread over a relatively large space, dark galaxies should have been shredded long ago. They are either recent arrivals to Coma or a lot stronger than they appear.

From what researchers have learned so far, dark galaxies seem to have been lurking for many billions of years. They are located throughout their home clusters, suggesting that they've had a long time to spread out among the other galaxies. And the meager stars they have are mostly red, indicating that they are very old. With this kind of long-term survival, dark galaxies probably have a hidden strength, most likely due to dark matter.

All galaxies are loaded with dark matter, a mysterious substance that reveals itself only via gravitational interactions with luminous gas




Hundreds of dark galaxies lurk about 340 million light-years away in the Coma galaxy cluster (pictured). Most of the splotches of light in this image are galaxies. Yellow circles mark the locations of recently found dark galaxies, too faint to be seen here.

IMAGE: DEAN ROWE, ADAPTED BY C. CROCKETT (SOURCE: P. VAN DOKKUM *ET AL*)

and stars. Much of that dark matter sits in an extended blob (known as the halo) that reaches well beyond the visible edge of a galaxy. On average, dark matter accounts for about 85 percent of all the matter in the universe. Within the central regions of the dark galaxies in Coma, dark matter must make up about 98 percent of the mass for there to be enough gravity to keep the galaxy intact, van Dokkum and colleagues say. Dark galaxies appear to have similar fractions of dark matter focused near their cores as the Milky Way does throughout its broader halo.

Astronomers had never seen such a strong preference for dark matter in galaxies so large. The initial cache of galactic enigmas lured a slew of researchers to the hunt. They pored over existing images of Coma and other clusters, looking for more dark galaxies. These galaxies are so faint that they could easily blend in with a cluster's background light or be mistaken for reflections within a telescope. But once the galaxy hunters knew what to look for, they were not disappointed — those first 47 were just the tip of the iceberg.

Looking at old images of Coma taken by the Subaru telescope in Hawaii, Koda and colleagues easily confirmed that those 47 were really there. But that wasn't all. They found a total of 854 dark galaxies, 332 of which appeared to be roughly the size of the Milky Way (*SN: 7/25/15, p. 11*). They calculated that Coma could harbor more than 1,000 dark galaxies of all sizes — comparable to its number of known galaxies. Astronomer Christopher Mihos of Case Western Reserve University in Cleveland and colleagues, reporting in 2015 in *Astrophysical Journal Letters*, found three more in the Virgo cluster, a more sparsely populated but closer gathering of galaxies that's a mere 54 million light-years away.

In June, van der Burg and collaborators reported another windfall in *Astronomy & Astrophysics*. Using the Canada-France-Hawaii Telescope atop Mauna Kea in Hawaii, they measured the masses of several galaxy clusters. Taking a closer look at eight clusters, all less than about 1 billion light-years away, the group found roughly 800 more ultradiffuse galaxies.

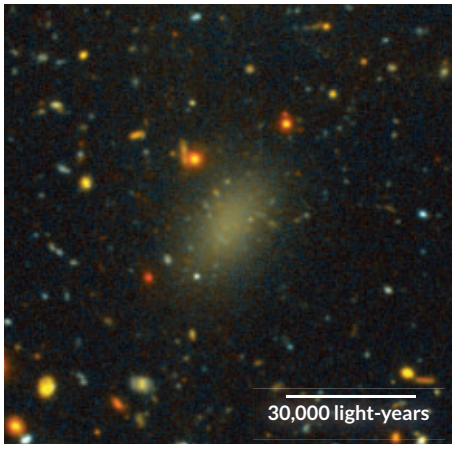
"As we go to bigger telescopes, we find more and more," says Michael Beasley, an astrophysicist at Instituto de Astrofísica de Canarias in Santa Cruz de Tenerife, Spain. "We don't know how many there are, but we know there are a lot of them." There could even be more dark galaxies than bright ones.

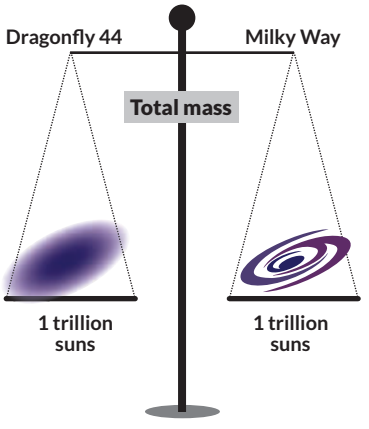
## Nature vs. nurture

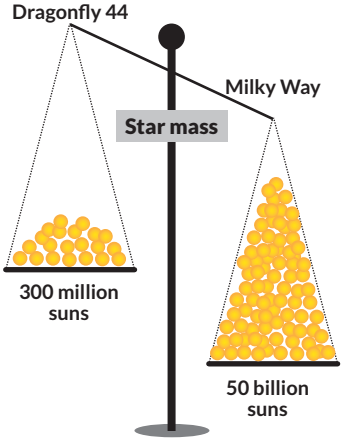
What dark galaxies are and how they formed is still a mystery. There are many proposals, but with so little data, few conclusions. For the vast majority of dark galaxies, researchers know only how big and how bright each one is. Three so far have had their masses measured. Of those, two appear to have more in common masswise with some of the small galaxies that orbit the Milky Way, while the third is as massive as our galaxy itself — roughly 1 trillion times as massive as the sun.

A dark galaxy in the Virgo cluster, VCC 1287, and another in Coma, Dragonfly 17, each have a total mass of about 70 billion to 90 billion suns. But only about one one-thousandth of that or less is in stars. The rest is dark matter. That puts the total masses of these two galaxies on par with the Large Magellanic Cloud, the largest of the satellite galaxies that orbit the Milky Way. But focus on just the mass of the stars, and the Large Magellanic Cloud is about 35 times as large as Dragonfly 17 and roughly 100 times as large as VCC 1287.

A galaxy dubbed Dragonfly 44, however, is another story. It's a dark beast, weighing about as




**Same but not** Dark galaxy Dragonfly 44 (pictured) is a ghostly behemoth, weighing about as much as the Milky Way — roughly 1 trillion times the mass of the sun — but with a mere 1 percent of our galaxy's stars (stellar mass comparison at right).

FROM LEFT: P. VAN DOKKUM, R. ABRAHAM, GEMINI OBSERVATORY/AURA; E. OTWELL

much as the entire Milky Way and made almost entirely of dark matter, van Dokkum and colleagues report in September in *Astrophysical Journal Letters*. "It's a bit of a puzzle," Beasley says. "If you look at simulations of galaxy formation, you expect to have many more stars." For some reason, this galaxy came up short.

The environment may be to blame. A cluster like Coma grows over time by drawing in galaxies from the space around it. As galaxies fall into the cluster, they feel a headwind as they plow through the hot ionized gas that permeates the cluster. The headwind can strip gas from an incoming galaxy. But galaxies need gas to form stars, which are created when self-gravity crushes a blob of dust and gas until it turns into a thermonuclear furnace. If a galaxy falls into the cluster just as it is starting to make stars, this headwind might remove enough gas to prevent many stars from forming, leaving the galaxy sparsely populated.

Or maybe there's something intrinsic to a galaxy that turns it dark. A volley of supernovas or a prolific burst of star formation might drive gas out of the galaxy. Nicola Amorisco of the Max Planck Institute for Astrophysics in Garching, Germany, and Abraham Loeb of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass., suggest that ultradiffuse galaxies start off as small galaxies that spun rapidly as they formed. All galaxies rotate, but perhaps dark galaxies are a subset that twirl so fast that their stars and gas have spread out, turning them into diffuse blobs rather than star-building machines.

To test these and other ideas, astronomers are focused on two key pieces of information: the masses of these galaxies and their locations in the universe. Mass can help researchers distinguish between formation scenarios, such as whether or not dark galaxies are failed Milky Way–like behemoths. A survey of other locales would indicate whether dark galaxies are unique to big clusters such as Coma, suggesting that the environment plays a role in their creation. But if they turn up outside of clusters, isolated or with small groups of galaxies, then perhaps they're just born that way.

There's already a hint that dark galaxies depend more on nature than nurture. Yale astronomer Allison Merritt and colleagues reported in October online at arXiv.org that four ultradiffuse galaxies lurk in a small galactic gathering about 88 million light-years away, indicating that clusters aren't the only place dark galaxies can be found. And van der Burg, in his survey of eight clusters, found that dark galaxies make up the same fraction of all galaxies in a cluster regardless of cluster mass — at least, for clusters weighing between 100 trillion and 1 quadrillion times the mass of the sun. About 0.2 percent of the mass of the stars is tied up in the dark galaxies. Since all eight clusters host roughly the same relative number of dark galaxies, that suggests that there is something intrinsic about a galaxy that makes it dark, van der Burg says.

What this all means for understanding how galaxies form is hard to say. These cosmic specters might be an entirely new entity that will require new ideas about galaxy formation. Or they could be one page from the galaxy recipe book. Timing, location and luck might send some of our heavenly neighbors toward a bright future and force others to fade into the background. Perhaps dark galaxies are a mixed bag, the end result of many different processes going on in a variety of environments.

"I see no reason why the universe couldn't make these things in many ways," Abraham says. "Part of the fun over the next few years will be to figure out which is in play in any particular galaxy and what sort of objects the universe has chosen to make."

What is clear is that as astronomers push to new limits — fainter, farther, smaller — the universe turns up endless surprises. Even in Coma, a locale that has been intensively studied for decades, there are still things to discover. "There's just a ton of stuff out there that we're going to find," Abraham says. "But what that is, I don't know." ■

## Why so light on stars?

The study of dark galaxies is in its infancy. Questions about their formation outweigh answers.

**Failed Milky Ways** Some dark galaxies could be relative heavyweights — comparable to the Milky Way — that were somehow prevented from forming stars by something in their surrounding environment.

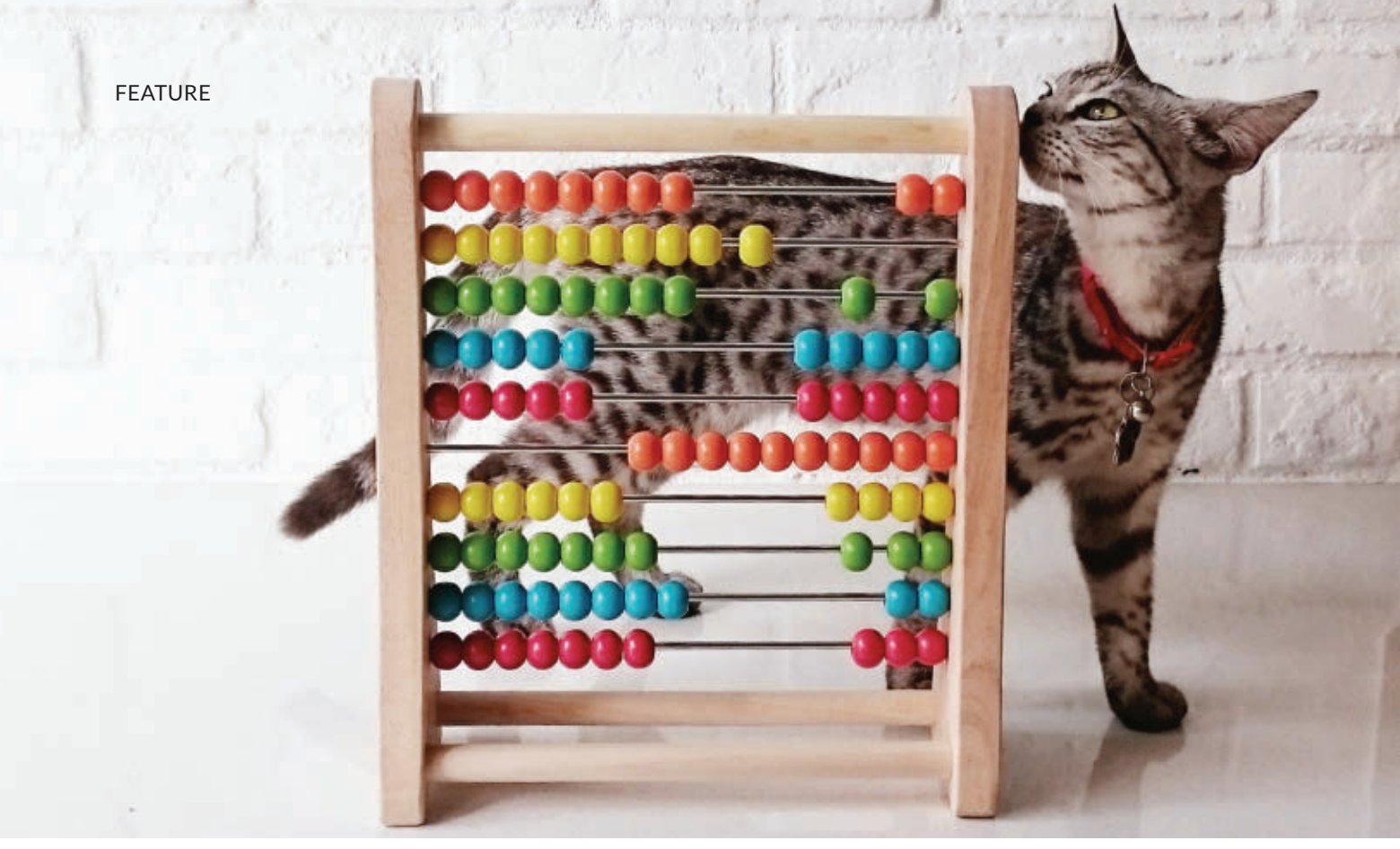
**Inflated lightweights** Tiny galaxies could be stretched apart like taffy by gravity from other nearby galaxies, spreading their relatively few stars across vast distances.

**Galactic regurgitators** A flurry of exploding stars or a prolific burst of star birth could hurl gas away from a galaxy — gas needed to form additional stars — and doom it to a life of darkness.

**Rapid rotators** Some small galaxies might begin life twirling faster than normal, eventually spreading thin as they whip gas and stars to their outskirts.

### Explore more:


- Pieter van Dokkum *et al*. "A high stellar velocity dispersion and ~100 globular clusters for the ultra-diffuse galaxy Dragonfly 44." *Astrophysical Journal Letters*. September 1, 2016.



# ANIMAL MATH

## Searching the barnyard and zoo for the evolutionary roots of human number crunching

**By Susan Milius**

When Christian Agrillo runs number-related experiments in his lab, he wishes his undergraduate subjects good luck. For certain tests, that's about all he says. Giving instructions to the people would be unfair to the fish.

Agrillo, of the University of Padua in Italy, is finishing up several years of pitting humans against fish in trials of their abilities to compare quantities. He can't, of course, tell his angelfish or his guppies to choose, say, the larger array of dots. So in recent tests he made the bemused students use trial and error too.

"At the end, they start laughing when they find they are compared with fish," he says. Yet the fish versus humans face-offs are eye-opening comparisons in his search for the deep evolutionary basis of what has blossomed into human mathematics. If it turns out that fish and people share some idiosyncrasies of their number sense (like spidey sense, except focused on quantities rather than danger), those elements might in theory date from a common ancestor more than 400 million years old. Comparisons of animals' mental powers are "the paleontology of cognition," Agrillo says.

No one seriously argues that animals other than people have some kind of symbolic numeral system, but nonhuman animals — a lot of them — can manage almost-math without numbers.

"There's been an explosion of studies," Agrillo says. Reports of a quantity-related ability come from chickens, horses, dogs, honeybees, spiders, salamanders, guppies, chimps, macaques, bears, lions, carrion crows and many more. And nonverbal number sensing, studies now suggest, allows much fancier operations than just pointing to the computer screen that shows more dots.

News stories on this diversity often nod to the idea that such a broad sweep of numberlike savvy

Cats show quantity-related abilities. Without training, cats can pick out differences between groups of a few small objects, such as 2 versus 5, but the felines may be using visual shortcuts.

YINGHUITAY/GETTY

across the animal tree of life could mean that animals all inherited rudiments of quantification smarts from a shared ancestor. Some scientists think that idea is too simple. Instead of inheriting the same mental machinery, animals could have just happened upon similar solutions when confronting the same challenge. (Birds and bats both fly, but their wings arose independently.)

Chasing down those deep origins means figuring out how animals, including humans too young or too rushed, manage quantitative feats without counting. It's not easy. Putting together what should be a rich and remarkable story of the evolution of nonverbal number sense is just beginning.

## Counting dog treats

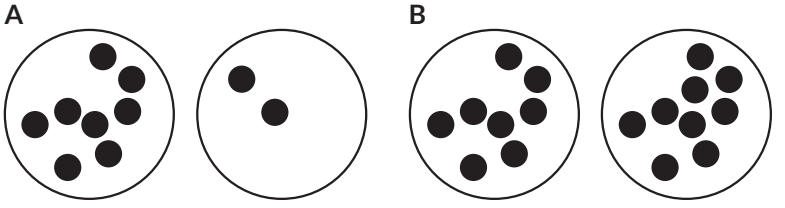
For a sense of the issues, consider the old and the new in dog science. Familiar as dogs are, they're still mostly wet-nosed conundrums when it comes to their number sense.

When food is at stake, dogs can tell more from less, according to a string of laboratory studies over more than a decade. And dogs may be able to spot cheating when people count out treats. Dog owners may not be amazed at such food smarts, but the interesting question is whether dogs solve the problem by paying attention to the actual number of goodies they see, or some other qualities.

An experiment in England in 2002, for instance, let 11 pet dogs settle down in front of a barrier that researchers then moved so the dogs could get a peek at a row of bowls. One bowl held a Pedigree Chum Trek treat. The barrier went up again, and researchers lowered a second treat into a bowl behind the screen, or sometimes just pretended to. When the barrier dropped again, the dogs overall stared a bit longer if only one treat was visible than if 1 + 1 had indeed equaled 2. Five of the dogs, in an extra test, also stared longer on average after a researcher covertly sneaked an extra treat into a bowl and then lowered the barrier on the unexpected 1 + 1 = 3.

Dogs could in theory recognize funny business by paying attention to the number of treats — or the treats' "numerosity," as researchers often call a quantity recognized nonverbally. But, depending on the design of a test, dogs might also get the right answers by judging the total surface area of treats instead of their numerosity. A multitude of other clues — density of objects in a cluster, a cluster's total perimeter or darkness and so on — would also work. Researchers lump those giveaways under the term "continuous" qualities, because

**Reckoning with Weber's law** Quick, which of the two circles in each pair has more dots in it? Weber's law predicts that the answer comes easier when object numbers in a pair are very different (8 versus 2) and/or involve a small number instead of two large ones (8 versus 9).



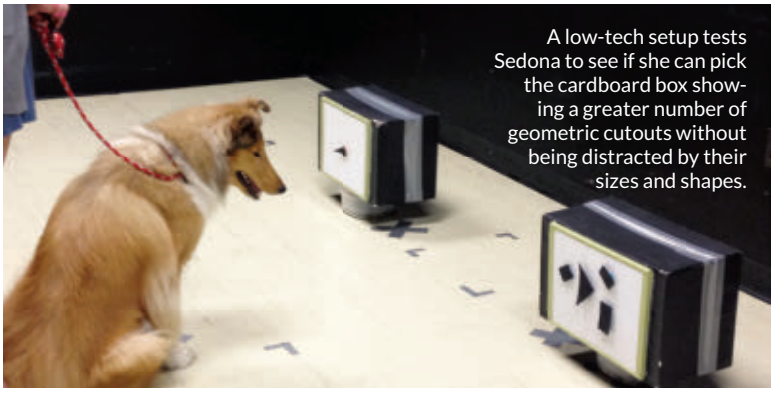

they change in a smooth continuum of increments instead of in the discrete 1, 2, 3.

The continuous qualities present a real staring-at-the-ceiling, heavy-sigh challenge for anyone inventing a numerosity test. By definition, nonverbal tests don't use symbols such as numbers, so an experimenter has to show something, and those somethings inevitably have qualities that intensify or dwindle as the numerosity does.

To at least see whether dogs evaluate total area to choose more food, Krista Macpherson of the University of Western Ontario in Canada devised a task for her rough collie Sedona. The dog had already served as an experimental subject in Macpherson's earlier test of whether real dogs would try to seek help for their owners in danger, as TV's trusty Lassie did. Sedona hadn't tried to seek help for Macpherson (no dog in the test aided its owner), but she had proved amenable to doing lab work, especially for bits of hot dog or cheese.

Sedona was put to work to select whichever of two magnet boards had a greater number of geometric shapes fastened to it. Macpherson varied the dimensions of black triangles, squares and rectangles so that their total surface area wasn't a reliable clue to the right answer.

The idea came from an experiment involving monkeys that reacted to a computer touch screen. But "I'm all cardboard and tape," Macpherson says. Sedona was perfectly happy to look at two

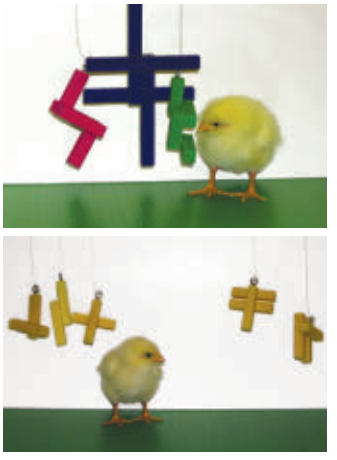


A low-tech setup tests Sedona to see if she can pick the cardboard box showing a greater number of geometric cutouts without being distracted by their sizes and shapes.

FROM TOP: J. HIRSHFELD; K. MACPHERSON

magnet boards fastened to cardboard boxes on the ground and then indicate her choice by knocking over a box.

Sedona in the end triumphed at picking the box with more geometric thingies regardless of area, though the project took considerable effort from both woman and beast. The dog worked through more than 700 trials, starting as simply as 0 versus 1 and eventually scoring better than chance scrutinizing bigger magnitudes, such as 6 versus 9, Macpherson and William A. Roberts reported in *Learning and Motivation* in 2013. (Eight versus nine finally stumped the collie, but more on patterns in accuracy later.) In a 2016 paper in *Behavioural Processes*, another lab hailed the Sedona research as the "only evidence of dogs' ability to use numerical information."



Newly hatched chicks form strong bonds with dangling assemblages of plastic (top). Researchers tested whether that led the chicks to focus on the actual number (as a human would say) of objects in a choice of 2 versus 3 friends (bottom).

## More is better

Dogs might have number sense, but when, or how much, they use it is another matter, notes Clive Wynne of Arizona State University in Tempe, a coauthor of that 2016 paper. To see what dogs do in more natural situations, he and Maria Elena Miletto Petrazzini of the University of Padua designed a test offering pets at a doggie daycare a choice of two plates of cut-up treat strips. A mix of breeds considered such options as a few big treat strips versus a smaller total amount of treats cut up into numerous small pieces. The dogs, without Sedona's arduous training, went for the greater total amount of food, regardless of the number of pieces. Of course they did; it's food — more is better. Without controls, food tests may not be measuring numerosity at all.

It's not just edibility that affects whether an animal pays attention to numerosity. Experience with similarity or differences in objects can matter. Rosa Rugani, also at Padua, has pioneered studying number sense in recently hatched chicks, which can learn experimental procedures fast if she gets them motivated. "One of the more fascinating challenges of my job is to come up with 'games' the chicks like to play," she says.

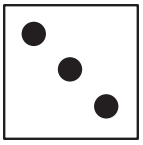
Newly hatched chicks can develop a strong social attachment to objects, as if little plastic balls or ragged crosses of colored bars were pals to huddle near in a flock. Taking advantage of this tendency, Rugani let day-old chicks imprint on either two or three objects. Then she watched them choose between two little flocks of novel pals to toddle over to. If the potential buddy-objects in a flock looked identical to each other, the chicks in the test typically just moved near the larger cluster or largest object. But if the buddies in each group had individual quirks, mixing colors, shapes and sizes, the chicks paid attention to numerosity. Those imprinted on three pals were a bit more likely to club with three different kinds of pals; those imprinted on the pairs more often clubbed with the twos.

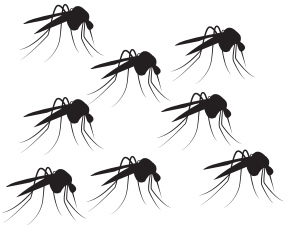
Some animals can deal with what people would call numerical order, or ordinality. Rats have learned to choose a particular tunnel entrance, such as the fourth or 10th from the end, even when researchers fiddled with distances between entrances. Five-day-old chicks rewarded for pecking at an item in a sequence, the fourth hole or the third jar, still showed a preference for position when researchers lengthened the distances between options or even moved the whole array.

Rhesus monkeys react if researchers violate rules of addition and subtraction, as dogs seemed to do in the Chums experiment. Chicks can track additions and subtractions too, well enough to pick the card hiding the bigger result. The chicks can also go one better. Rugani and colleagues have shown that chicks have some sense of ratios, for example choosing between mixes of red and green dots to match a ratio they learned from such mixes as 18 greens mingling with 9 reds.

A sense of numerosity itself, regardless of volume or surface area, may not be limited to fancy vertebrate brains. One recently published test takes advantage of overkill among golden orb-web spiders (*Nephila clavipes*). When they have a crazy run of luck catching insects faster than they can eat them, the spiders wrap each catch in silk and

**In a blink** Take a quick glance at the clusters to the right before reading more. You probably just *saw* that the left-hand box had three dots, but you'd have to count the mosquitoes on the right. That immediate grasp of small quantities is called subitizing, an ability that people and other animals may share.





CHICKS: R. RUGANI *ET AL/DEVELOPMENTAL SCIENCE* 2010; MOSQUITO: M. TELFER

fasten it with a single strand to dangle from the center of the web. Turning this hoarding tendency into a test, Rafael Rodríguez of the University of Wisconsin–Milwaukee tossed bits of mealworms of different sizes into the web as spiders created a dangling treasure trove. Then shooing the spider off the web, he snipped the strands and watched how long the spiders searched for their stolen meals. Losing a greater volume of food inspired more strumming of the web and searching about. But losing four items instead of just one or two increased the search time even more, Rodríguez and his colleagues reported in 2015 in *Animal Cognition*. It's not just volume of food in a hoard, they argue. Numerosity has its own effects.

## At a glance

Nonhuman animals don't have human language for counting, so researchers studying behavior talk about an "approximate number system" that allows for good-enough estimates of quantities with no real counting. One of the features of this still mysterious system is its declining accuracy in comparing bigger numbers that are very close together, the trend that made Sedona the collie's struggles as noteworthy as her successes.

As the ratios of the two quantities Sedona had to compare drew closer to 1, she was more prone to make mistakes. Her scores worsened as she moved from 0.11 (comparing 1 to 9), 0.2 (1 to 5) and so on. She never conquered the fiendish 8 versus 9. That same trend, described by what's called Weber's law, shows up in humans' nonverbal approximate number system as well as in those of other animals.

When Agrillo tested guppies against humans, both fell behind in accuracy for such difficult comparisons as 6 versus 8. But for small quantities, both fish and people performed well, he and colleagues reported in 2012. People and fish could tell 3 dots from 4 about as reliably as 1 dot from 4. Researchers have long recognized this instant human ease of dealing with very small quantities, calling it subitizing: suddenly just *seeing* that there are three dots or ducks or daffodils without having to count them. Agrillo suspects the underlying mechanism will prove different from the approximate number systems, though he describes this as a minority view.

The similarity between guppies and people in subitizing skill doesn't prove it's a shared inheritance from that ancient common ancestor several hundred million years ago, Agrillo says. Yet the similarity does raise the possibility.

## Who's (sort of) counting?

Symbolic numbers do marvels for humankind, but for millions of years, other animals without full powers to count have managed life-and-death decisions about magnitude (which fruit pile to grab, which fish school to join, whether there are so many wolves that it's time to run). — *Susan Milius*

**Oriental fire-bellied toad**
*Bombina orientalis* is one of the few amphibians tested for number sense. Test animals showed more interest in eight yummy mealworms than four when treats were the same size. A visual shortcut like surface area may make more of a difference than numerosity. SOURCE: G. STANCHER *ET AL/ANIM. COGN.* 2015

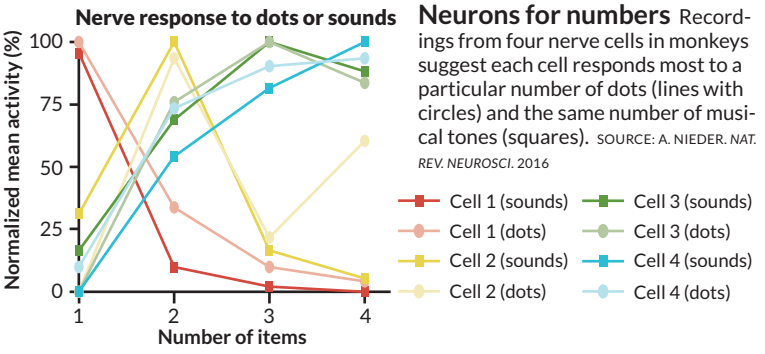
**Orangutan**
Much of the research on nonhuman number sense involves chimps and various monkeys. A zoo orangutan trained to use a touch screen was able to pick which of two arrays had the same number of dots, shapes or animals shown in a previous sample. SOURCE: J. VONK/*ANIM. COGN.* 2014

**Cuttlefish**
The first test of number sense in *Sepia pharaonis*, published in 2016, reports that cuttlefish typically move to eat a quartet of shrimp rather than a threesome, even when the three shrimp are crowded around so the density is the same as in the quartet. SOURCE: T.-I. YANG AND C.-C. CHIAO/*PROC. R. SOC. B* 2016

**Honeybee**
Honeybees that learned to tell two from three dots did pretty well when tested with dots of different colors, oddly positioned among distracting shapes or even replaced with yellow stars. SOURCE: GROSS *ET AL/ PLOS ONE* 2009

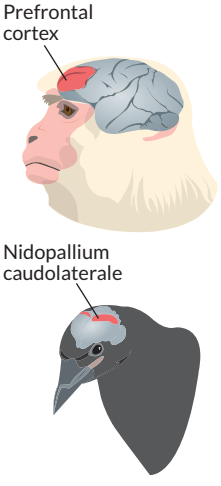
**Horse**
Horses have a special sad place in the history of number studies because the famed "Clever Hans" turned out to be solving arithmetic problems with cues from observers' body language. A different study finds that horses can tell two dots from three, but might be using area as a clue. SOURCE: C. ULLER AND J. LEWIS/ *ANIM. COGN.* 2009

FROM TOP: VASSIL/WIKIMEDIA COMMONS; M_EWELL_YOUNG/INATURALIST.ORG (CC BY-NC 4.0); STICKPEN/WIKIMEDIA COMMONS; KEITH MCDUFFEE/FLICKR (CC BY 2.0); JAMES WOOLLEY/FLICKR (CC BY-SA 2.0)




**Neurons for numbers** Recordings from four nerve cells in monkeys suggest each cell responds most to a particular number of dots (lines with circles) and the same number of musical tones (squares). SOURCE: A. NIEDER. *NAT. REV. NEUROSCI.* 2016

Struggling to separate some pure response to numerosity from all the confounding surface areas and other continuous qualities may not even be the most important question, says Lisa Cantrell, now at the University of California, Davis. Human babies, as an example of noncounting animals, might start figuring out the world by relying on these other confounders and grow into their numerical abilities, she and Linda Smith of Indiana University, Bloomington, suggested in 2013. The hypothesized approximate number system might be part of some more general way of perceiving the world, which can draw on multiple clues to get a clearer sense of quantity. Cantrell and Smith called their version of the idea the "signal clarity hypothesis."




**Brain basics** Bird brains lack a fancy six-layered outer cortex. But carrion crows have a brain area (nidopallium caudolaterale) rich in nerve cells that respond to quantity. In the macaque (top), number neurons are in a different area, mainly the prefrontal cortex.

## Into their heads

Studying behavior alone isn't enough to trace the inheritance of any part of number savvy, says Andreas Nieder of the University of Tübingen in Germany. "At the behavioral level, it may look as if number estimation follows the same laws, but the underlying neural code could actually look quite different."

He's not going as far afield as fish yet, but Nieder and colleagues have looked at how monkey and bird brains handle quantity. The researchers described neurons (nerve cells) in the brains of carrion crows (*Corvus corone corone*) that function much like those in rhesus macaques.

Research in monkeys over the last 15 years has identified what Nieder calls "number neurons." They could have multiple functions, but each responds to a specific number of whatevers, be it six crows or six crowbars. Some number neurons respond to sight, some to sound, and amazingly, some to either.

The neurons could be responding to increasing total surface area or density or darkness. But researchers have varied one aspect at a time, and used multiple imaging and pharmacological techniques, to argue that as far as strenuous efforts can tell, these neurons detect the actual numerosity.

Individual neurons in parts of a monkey brain have their own preferred number and respond most strongly to it and less so to neighboring numbers. The neurons for three get less excited for two and four, while others light up at four. In 2015, Nieder and colleagues started untangling how monkey neurons handle zero, suggesting the beginnings of an ability to treat "nothing there" as an abstract numerosity of zero.

These neurons lie in notable places: the six-layered neocortex of the parietal and frontal lobes of the brain. That's territory that primates boast about, a feature of mammalian brain structure credited with allowing human mental capacities to reach such heights. Nonmammalian vertebrates, including birds, don't have a multilayered neocortex. Yet Nieder and colleagues have, for the first time, detected individual neurons in the bird brain that fire in response to numerosities much as primate number neurons do.

The bird versions of number neurons lie in a relatively newfangled area of the avian brain called the nidopallium caudolaterale, or NCL. It didn't exist as such, nor did the primate's precious neocortex, in the reptile-ish ancestors that mammals and birds last shared some 300 million years ago. Both the bird NCL and the primate number neuron zones arose from the same tissue, the pallium. In mammals, that ancient pallium morphed into layers of neocortex tissue, in birds the transformation went a different way.

For the number sense tingling through specialized neurons in birds and primates alike, similarity does not strictly mean shared inheritance, Nieder wrote in the June *Nature Reviews Neuroscience*. The systems of number neurons probably specialized independently.

Finding some brain structures to compare across deep time is a promising step in fathoming the evolution of animal number sense, but it's just a beginning. There are many questions about how the neurons work, not to mention what's going on in all those other brains that contemplate quantity. For now, looking across the tree of life at the crazy abundance of number smarts, which may or may not be related but are certainly numerous, the clearest thing to say may be just: Wow. ■

## Explore more

■ Andreas Nieder. "The neuronal code for number." *Nature Reviews Neuroscience*. June 2016.

A. NIEDER/*NAT. REV. NEUROSCI.* 2016

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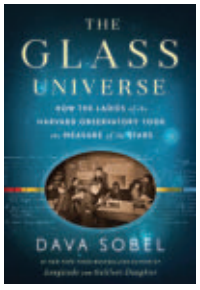


**The Glass Universe**
*Dava Sobel*
VIKING, $30

BOOKSHELF

# Astronomy's unsung heroines get their due

In the early 1880s, Harvard Observatory director Edward Pickering put out a call for volunteers to help observe flickering stars. He welcomed women, in particular — and not just because he couldn't afford to pay anything.

At the time, women's colleges were producing graduates with "abundant training to make excellent observers," Pickering wrote. His belief in women's abilities carried over when he hired staff, even though critics of women's higher education argued that women "originate almost nothing, so that human knowledge is not advanced by their work."

Pickering and his "harem" sure proved the critics wrong.

In *The Glass Universe*, science writer Dava Sobel shines a light on the often-unheralded scientific contributions of the observatory's beskirted "computers" who helped chart the heavens. By 1893, women made up nearly half of the observatory's assistants, and dozens followed in their footsteps.

These women toiled tirelessly, marking times, coordinates and other notations for photographic images of the sky taken nightly and preserved on glass plates — the glass universe. These women's routine mapping of the stars gave birth to novel ideas that advanced astronomy in ways still instrumental today — from how stars are classified to how galactic distances are measured.

Using diaries, letters, memoirs and scientific papers, Sobel recounts the accomplishments of these extraordinary women, going into enough scientific detail (glossary included) to satisfy curious readers and enough personal detail to bring these women's stories to life.

Sobel traces the origin of the glass universe back to heiress Anna Palmer Draper. The book opens in 1882 with her exulting in hosting a party for the scientific glitterati under the glowing and novel Edison incandescent lights. Her husband, Henry Draper, a doctor and amateur astronomer, had pioneered a way to "fix" the stars on glass photographic plates. The resulting durable black-and-white images revealed spectral lines that could provide hints to a star's elements — and eventually so much more. Henry's premature death five days after the party launched Anna's philanthropic support of the Harvard Observatory and the creation of the glass universe.

Other women featured in the book had a more hands-on impact on astronomy. For instance, Williamina Fleming came to the United States as a maid. But Pickering soon recognized her knack for mathematics. At the observatory, she read "the rune-like lines of the spectra," Sobel writes, noticing patterns that led to the first iteration in 1890 of the Draper stellar classification system. That system, still used today, was later refined by the observations of other women.

Henrietta Leavitt, a promising Radcliffe College astronomy student slowly going deaf, joined the staff in 1895. While meticulously tracking the changing brightness of variable stars, she noticed a pattern: The brighter a star's magnitude, the longer it took to cycle through all its variations. This period-luminosity law, published in 1912, became crucial in measuring the distance to stars. It underpinned Edwin Hubble's law on cosmic expansion and led to discoveries about the shape of the Milky Way, our solar system's place far from the galactic center and the existence of other galaxies.

The story belongs, too, to Pickering and his successor, Harlow Shapley. Perhaps partly motivated by economics at a time of shoestring budgets — in 1888, women computers earned just 25 cents per hour — these men not only recognized, but also encouraged and heralded the women's talent.

Sobel takes readers through World War II and a myriad of other moments starring women: first woman observatory head; first woman professor at Harvard (of astronomy, of course); discoveries of binary stars, the prevalence of hydrogen and helium in stars, and the existence of interstellar dust. In some cases, it took male astronomers to make those findings stick — the glass universe had a glass ceiling.

After World War II, radio astronomy emerged, and "the days of the human computer were numbered — by zeros and ones," Sobel writes. Using film to photograph the stars ended in the 1970s. But the glass universe is far from obsolete. The roughly half-million plates hold the ghosts of pulsars, quasars and other stellar phenomena not even imagined when the plates were made. They also offer the promise of more discoveries to come, perhaps by the next generation of women astronomers. — *Macon Morehouse*

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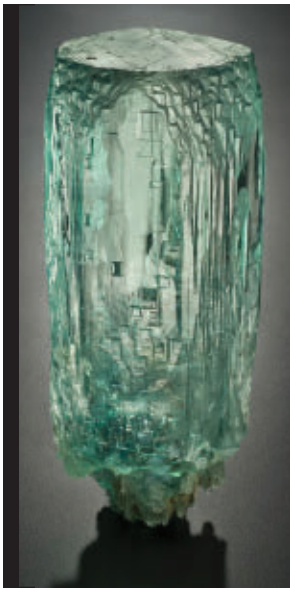

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# Three Society alumni named MacArthur Fellows

Two alumni of Society for Science & the Public's science fair competitions and one winner of the Science, Play and Research Kit (SPARK) competition were named 2016 MacArthur Fellows. Fellows are awarded five-year grants to support their notable research.

## The 2016 MacArthur Fellows include:

**DIANNE NEWMAN** (1987 and 1988 Intel ISEF finalist), a microbiologist at Caltech, investigates the role early bacteria played in shaping the Earth — from the planet's rock formations to its oxygen-dominated atmosphere. Newman also uses information about the evolution of ancient microbes to understand how modern disease-causing bacteria thrive. Her work could lead to more effective treatments for chronic infections such as those that affect cystic fibrosis patients.

**BILL THIES** (1997 Intel STS finalist), a computer scientist and senior researcher with Microsoft Research India, works on technologies to advance the social and economic well-being of low-income communities in the developing world. Thies' mobile-based technologies, which aid medical treatment, education and reporting social injustices, are relatively affordable and take into account obstacles faced by these communities such as limited internet access and low literacy rates.

**MANU PRAKASH** (first place winner of the Society's 2014 SPARK competition), an inventor and physical biologist at Stanford University, is interested in democratizing science. Prakash invents affordable devices to study complex problems in global health and ecological surveillance. One of his inventions, Foldscope, is a lightweight optical microscope with micrometer resolution that is made from a single sheet of paper integrated with electronics and lenses. It costs less than a dollar to produce.

**Read more about Newman's work:**
student.societyforscience.org/blog/doing-science/how-ancient-microbes-invented-metabolism

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OCTOBER 15, 2016

## Breaking bad science

*Science News* not only brings readers the latest scientific findings, but also explains how science works — or sometimes doesn't work. In "Blame bad incentives for bad science" (*SN Online: 10/21/16*), on the *Science News* blog *Scicurious*, **Bethany Brookshire** takes a closer look at how the "publish or perish" system may be derailing the scientific process. Read more at **bit.ly/SN_badscience**.

### Join the conversation

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### Nuts about Neandertals

*Recent genetic analyses of populations around the world showed that a wave of ancient humans left Africa about 50,000 to 72,000 years ago. All non-Africans alive today originated from this single wave,* ***Tina Hesman Saey*** *reported in "One Africa exodus populated globe" (*SN: 10/15/16, p. 6*).*

"If the Neandertals were already present when *Homo sapiens* arrived on the scene, from whence did the Neandertals originate, and how did they get there ahead of the (true) humans?" **Peter Goodwin** asked.

"Neandertals didn't race ahead of humans out of Africa," **Saey** says. Some earlier ancestor of both modern humans and Neandertals migrated out of the continent long before either species came on the scene. "Neandertals evolved outside of Africa, possibly from *Homo heidelbergensis*. They 'grew up' in Europe and Southwest Asia and were already present when humans started to venture out of Africa" she says.

But once human ancestors ventured into new territories, they met up and mated with Neandertals and other hominids, **Bruce Bower** says. Scientists are studying physical changes in the bodies of various animal hybrids to understand signs of this ancient interbreeding, **Bower** reported in "The hybrid factor" (*SN: 10/15/16, p. 22*).

Online reader **Mark S.** wondered if hybridization could explain the similarities between even older hominids like *Homo naledi* and *Australopithecus,* which have collarbones and finger bones in common *(SN: 5/14/16, p. 12)*.

Biological anthropologist **Rebecca Ackermann** of the University of Cape Town in South Africa suspects hybridization helped shape the anatomy of *H. naledi* and other ancient hominid species, **Bower** says. But no DNA has been extracted from *H. naledi* fossils to explore that possibility. DNA from Spanish fossils does suggest that Neandertals and Denisovans may have interbred more than 430,000 years ago (*SN Online: 3/14/16*).

### Quantum leap through time

*Researchers teleported quantum particles over long distances in Canada and China. The feats could lay the groundwork for a quantum internet,* ***Emily Conover*** *reported in "New steps toward quantum internet" (*SN: 10/15/16, p. 13*).*

"Is there any chance that quantum communication could send messages to the past or future ... information time travel?" online reader **J Ferris** asked.

"Unfortunately, quantum mechanics does not allow faster-than-light communication — although it seems like it could at first blush," **Conover** says. Through entanglement, quantum particles appear to remotely affect one another instantaneously. But to transmit or receive actual information, other details about the measurement must be sent through normal light-speed channels. "That's a good thing," she says. "If faster-than-light communication were possible, communication back in time would be too, which would cause all kinds of weird paradoxes. You could talk to your parents before you were born and perhaps convince them not to have children."

### Failure to launch

*A star that vanished in 2009 may be the first confirmed case of a failed supernova. A faint infrared light and a black hole are all that remain of NGC 6946,* ***Christopher Crockett*** *reported in "Lost star may be failed supernova" (*SN: 10/15/16, p. 8*).*

**Jan Steinman** wondered if the star's collapse released enough gravitational energy for scientists to detect it using the Advanced Laser Interferometer Gravitational-Wave Observatory, or LIGO, which confirmed the existence of gravitational waves earlier this year.

Failed supernovas indeed produce gravitational waves detectable by LIGO, **Crockett** says. However, the waves are generated at the heart of stellar explosions, regardless of whether or not those explosions "fail" and collapse into black holes. It would be difficult to tell the difference between a supernova and a failed one from the gravitational waves alone, says Fermilab's **James Annis**.

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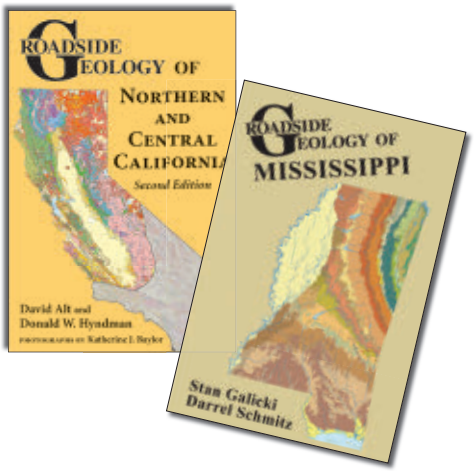


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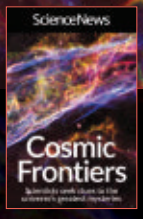


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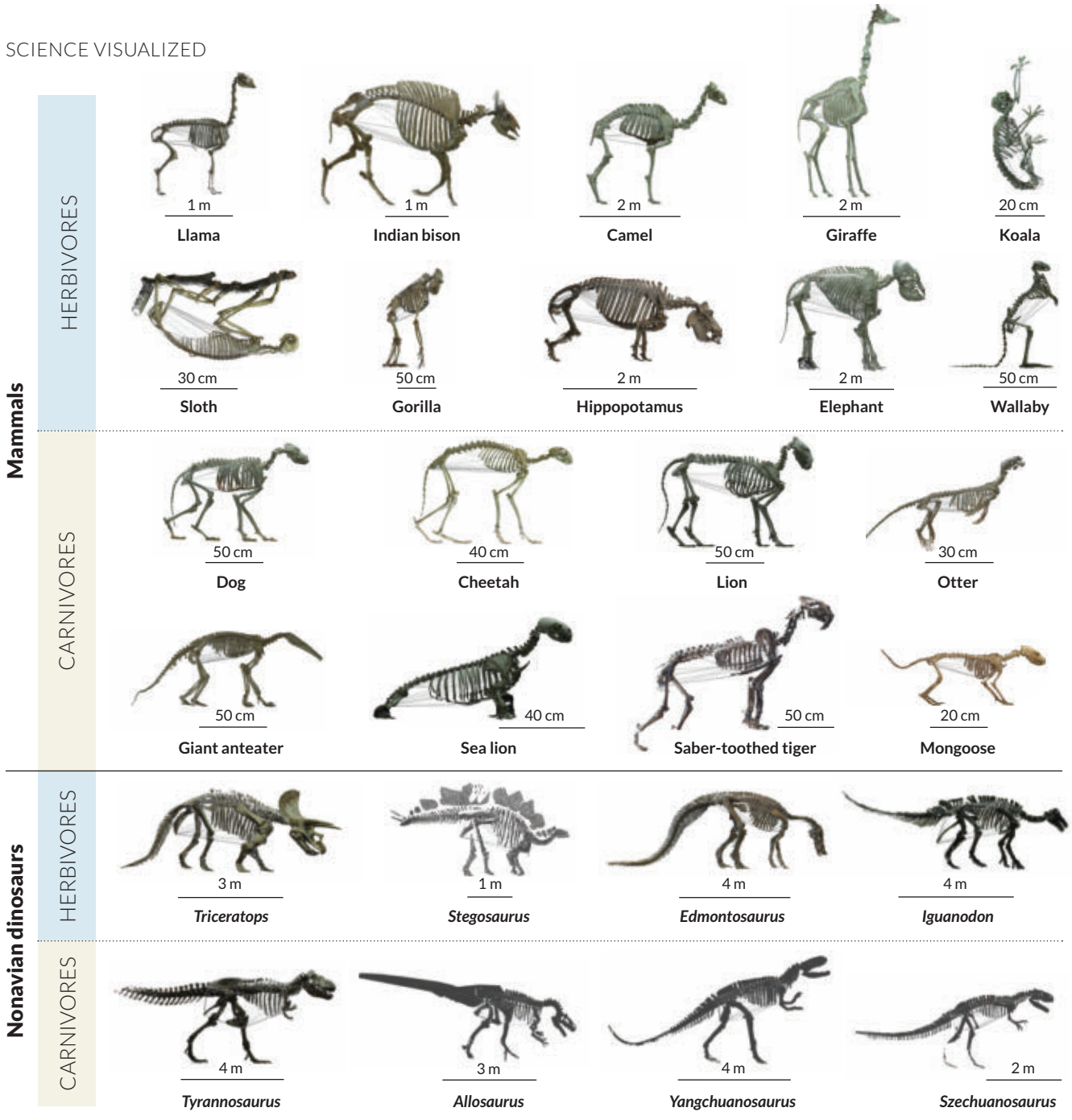


## Boning up on belly size

These skeletons are spilling their guts about the size of the body cavity that housed these animals' stomach and intestines.

Using digital 3-D scans of mounted skeletons (above), researchers estimated the body cavity volume in 126 species. Of the 76 mammal species, plant eaters had bigger bellies; their relative torso volumes were about 1.5 times as large as those of carnivores, researchers report online November 4 in the *Journal of Anatomy*.

The study is the first to quantitatively test the long-held idea that herbivores have bigger torsos, says Marcus Clauss of the University of Zurich. Plant eaters are thought to need extra space for complex systems that digest a leafy diet.

Surprisingly, Clauss and colleagues didn't find the same pattern in nonavian dinosaurs, birds or reptiles, but the researchers had fewer skeletons to compare. Of the 27 dinosaurs, for example, only four were carnivores.

Still, the research suggests that in tetrapods — four-limbed vertebrates — only mammalian herbivores have larger body cavities, raising questions about why that might be evolutionarily. "Everybody goes crazy about the long neck or the strange things" on an animal's head, Clauss says. But few scientists have focused on the torso's frame and how diet helps sculpt it over time. "This study emphasizes that the torso is an important part of overall body shape." — *Emily DeMarco*

M. CLAUSS ET AL/JOURNAL OF ANATOMY 2016

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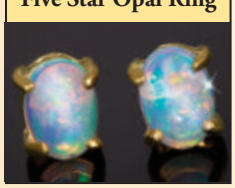

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