Brain Invaders | Depression Switch | 9/11 Cancers

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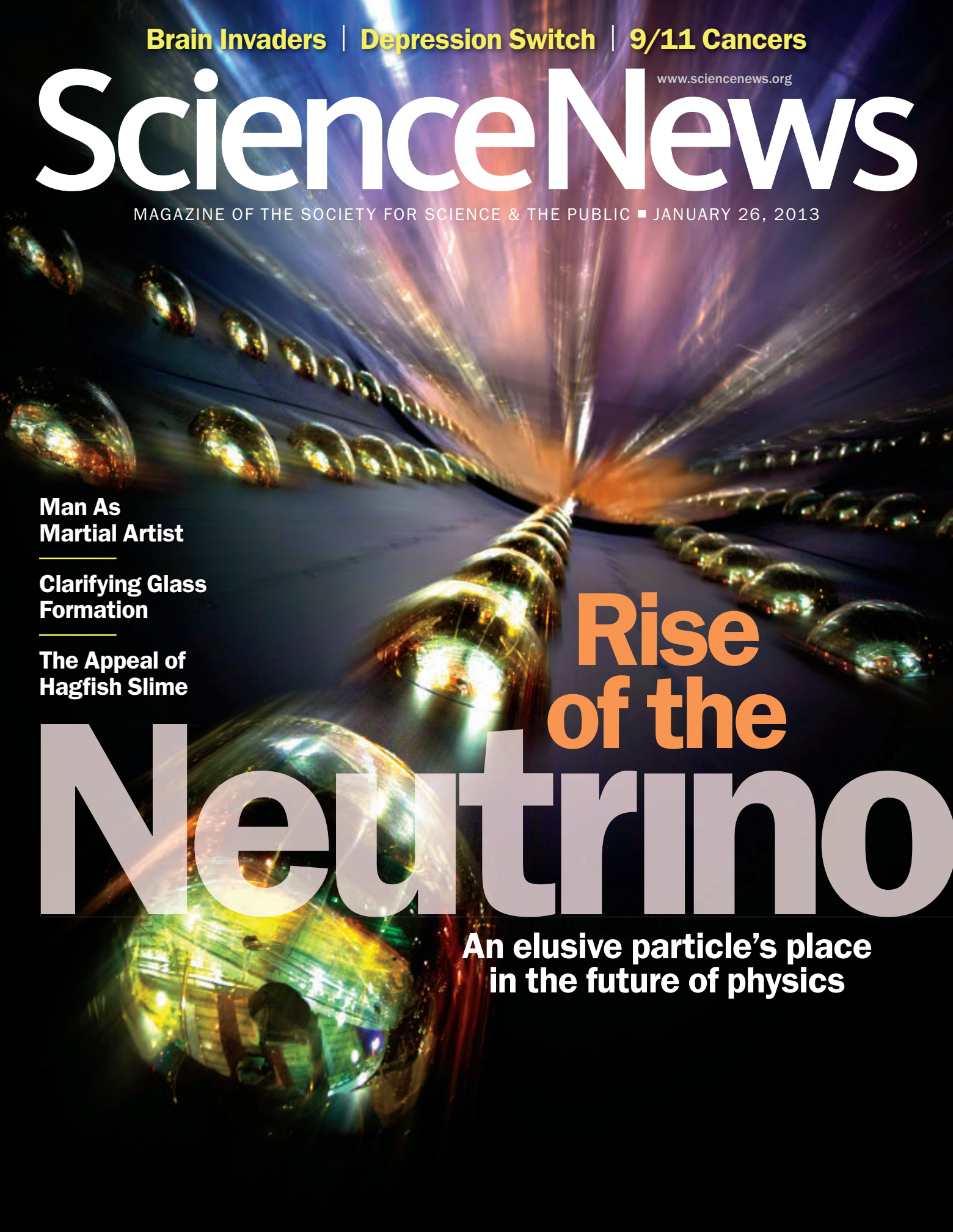
ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ JANUARY 26, 2013



Man As Martial Artist

Clarifying Glass Formation

The Appeal of Hagfish Slime

Rise of the Neutrino

An elusive particle's place in the future of physics

Revealed: Silver Dollar Secrets

One of the world's lowest mintage Silver Dollars may surprise you!

Everybody loves Silver Dollars. And it's not hard to figure out why. The feel of a hefty, gleaming Silver Dollar in your hand is hard to beat—especially when the coin is struck from 99.9% pure silver.

But even though Silver Dollar sized coins are struck all over the world, not all Silver Dollars are created equal. In fact, savvy collectors have known three exciting "secrets" about the Australian Koala Silver Dollar for years. Secrets *you* should know too!

Actual size 40.6 mm

#1: One of the World's Most Limited Silver Dollars
Insiders realize that MILLIONS fewer Koalas Silver Dollars are struck than most other silver coins. Annually, there are fewer Koalas Silver Dollars issued than any of the comparable silver coins of Canada, China, Austria, Mexico, or the United States. In fact, there are anywhere from **7 million to 39 million more** China Silver Pandas, Canadian Maple Leafs, or U.S. Silver Eagle dollars struck each year than there are Australian Koala Silver Dollars. There are a variety of factors that make a particular coin collectible, and the markets in some countries are much bigger than others, but many collectors place low mintage coins near the top of their "must have" list! Low mintages can sometime create tremendous demand when past year issues appear on the market. For example, the 2007 Silver Koala is currently being offered elsewhere for well over $100.

#2: Pure Australian Silver
Silver's allure is timeless. But today, the voracious appetite for silver from collectors, banks, and governments has made this precious metal hotter than ever! Over the last five years, the silver market has been volatile, as demand has often surpassed global supplies. The top-producing silver mine in the world is in Australia—and that single Australian mine produces nearly as much silver as all the mines in the U.S. combined. So it's no wonder that one Troy ounce Australian Koala Silver Dollars are prized by collectors and are highly sought-after.

#3: Government Guaranteed
Legal tender Silver Dollars are among the world's most popular coins. Buying Silver Dollars allows you to own pure silver with the absolute security of government guaranteed purity, weight, and authenticity. Each Australian Koala Silver Dollar bears this government guarantee struck directly into the surface of the coin!

Buy RISK FREE to avoid disappointment
Smart collectors are in for the long haul. They're building a family legacy in pure silver. Here's your chance to join them. You can get this coveted, limited-edition legal tender 2013 Koala Silver Dollar—**a coin that collectors around the world are scrambling to get their hands on**—at a price as low as $45.95 each!

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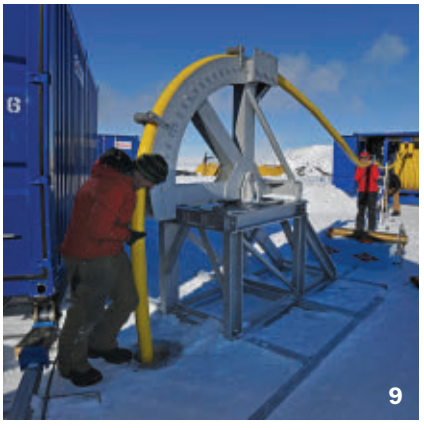

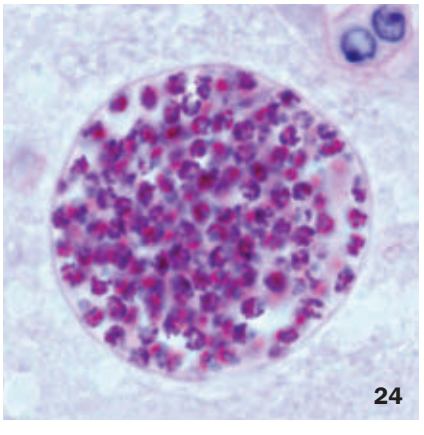

ScienceNews

In The News

Features

Departments

COVER Photomultiplier tubes line an antineutrino detector at China's Daya Bay experiment, which explores how the particles change form. *Roy Kaltschmidt/Lawrence Berkeley National Lab*

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FROM THE EDITOR

Science surprises, from neutrinos to parasites

Invisible energetic particles constantly flow through your body, passing through you like there's nothing there at all. A sneaky parasite lodges in your brain, where it may or may not work subtle changes on your personality. Both of these are examples of science that surprises — and fills one first with wonder and then a bevy of questions.

On Page 18, contributing correspondent Charles Petit outlines the latest probing of the mysteries of neutrinos, the ubiquitous subatomic players that only very rarely interact with other matter. While that makes them difficult to study, they can be detected and scientists have made progress in revealing neutrinos' shifty character: The particles transform into different subtypes as they travel. As Petit relates, the latest results suggest that these elusive particles could one day yield new clues to the universe's present imbalance of matter and antimatter. Without members of an ancient neutrino family, he notes, antimatter and matter might have annihilated each other very early in the universe's history. What surprises is the idea that such a tiny, seemingly insubstantial thing may have had such a substantial role in the cosmos.

The science of the single-celled *Toxoplasma gondii* is surprising in its possible implications — could a microbe that evolved to parasitize cats actually influence behavior in humans? Starting on Page 24, life sciences writer Susan Milius explores the evidence. Some studies have found that rats infected with *T. gondii* show more of a devil-may-care attitude, no longer avoiding the smells of cats, their predator. But while the infection is fairly common in humans, linking any behavioral changes in people to the parasite has been difficult. Studies do suggest that people who test positive for the infection are more likely to have been in a car accident. And, after puzzling over his own demeanor, one researcher who carries the parasite is probing more subtle personality shifts that might accompany infection.

These stories offer a reminder that you don't have to reach for science fiction to read about things far-out and mind-blowing. As fans of science know, the study of the natural world can be more compelling and stranger than any product of the imagination. The universe is chock-full of wonders, and the lifeblood of science is cataloging those wonders, surprising you at every step with new perspectives on the world you thought you knew. — *Eva Emerson, Editor in Chief*

PHILIP CHANNING

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—Darlene and Jack B., CA

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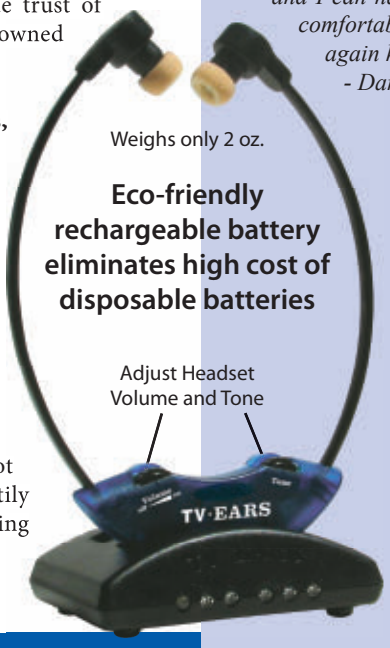
—Robert Forbes, M.D., California



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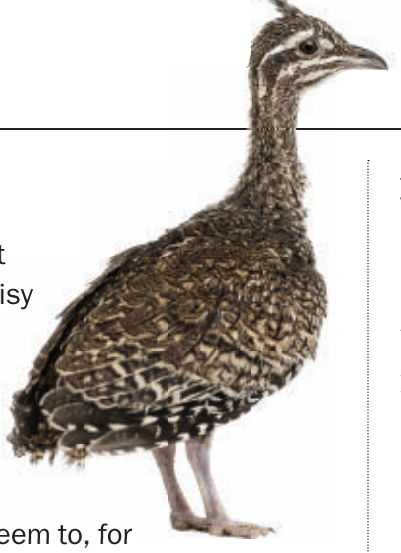
Say What?

Lombard effect */LAHM-bard eh-FEKT/ n.*

A speaker's involuntary raising of the voice — be it human or another animal's — while talking in a noisy environment. In experiments, volunteers have difficulty matching a target speech volume while listening to distracting noise. The Lombard effect is probably familiar to anyone who has ever heard someone who is wearing headphones try to talk, but not all animals show it — frogs don't seem to, for instance. Now, German researchers have found that female elegant crested tinamous (shown) increase their call volume when bombarded by noise. Because tinamous belong to one of the evolutionarily oldest bird groups, the team proposes in the Dec. 23 *Biology Letters* that this auditory phenomenon might go back to a common ancestor of birds and mammals. —*Allison Bohac*



Science Past | FROM THE ISSUE OF JANUARY 26, 1963

DOGS FOUND COLOR-BLIND — Some animals are able to distinguish colors but others are practically color-blind, Dr. Gerti Duecker, zoologist of the University of Muenster, West Germany, has determined by a series of tests. Dr. Duecker found cats and dogs to be color-blind, although there is some evidence that some dogs have a faint sense of color. The color vision of mice, rats and rabbits is also not positive. The golden hamster and the opossum are definitely color-blind. Horses, deer, sheep, pigs, squirrels and martens can perceive colors, but only in certain parts of the spectrum. A few species are receptive only to reds and greens.... Most monkeys and apes resemble man in their capacity to see colors, and the chimpanzee is the most versatile of all.

Science Future

February 11–13

The University of Tennessee, Knoxville hosts lectures, films, a concert and even a cake contest to celebrate Charles Darwin's birthday. See bit.ly/SFutdarwin

February 18

Learn how the recently discovered "slow" earthquake differs from typical quakes with geophysicist Gregory Beroza at the New Mexico Museum of Natural History and Science in Albuquerque. See bit.ly/SFslowquakes

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LIFE

The activity of just a few genes may be key to limb evolution. Read "Fins to limbs with flip of genetic switch."

Scientists analyze chemical forms in gorilla poop to reconstruct monthly shifts in the animals' diets. See "Feces study gets the poop on gorillas' diet."

EARTH

New satellite images dubbed "Black Marble" show nighttime lights across the globe. See "Earth in the black."

ATOM & COSMOS

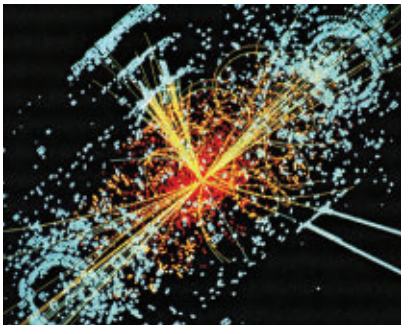
A nearby sunlike star may host five planets that weigh between two and six Earth masses. Read more in "Possible planet looks habitable."

Introducing | MISUNDERSTOOD LORIS

A few species of slow loris may have been hiding — not exactly in plain sight, but in oversimplified classification. The elusive double-tongued, venomous Bornean slow loris emerges from sleeping hideouts only at night and slips through tangles of branches. Variations in white face masks and other traits suggest the Bornean loris should be split off as a new species, *Nycticebus kayan,* along with two more new species, Rachel Munds of the University of Missouri and colleagues argue in the January *American Journal of Primatology*. Munds warns that the pet trade has ravaged wild populations of the stupifyingly cute primates. —*Susan Milius*

Science Stats | COLLISION MILESTONE

In December, the Large Hadron Collider near Geneva finished its first three-year run of smashing protons together (simulation of one particle collision shown). The LHC's biggest accomplishment was confirming the existence of the Higgs boson last July. SOURCE: CERN



6 million billion
Total number of proton-proton collisions at the LHC

10 billion
Collisions deemed to be of scientific interest

400
Collisions that were compatible with a Higgs-like particle

CLOCKWISE FROM TOP: ERIC ISSELEE/SHUTTERSTOCK; NASA, NOAA; CERN; © CH'IEN C. LEE

“All we’ve done is basically kicked them and said, ‘you need to be normal now.’” —GAUTHAM VENUGOPALAN, PAGE 8

In the News

STORY ONE

Sutter’s Mill meteorite is rich vein into early solar system

Rock preserves rare, fresh material from outer space

By Alexandra Witze

ERIC JAMES/NASA, P. JENNISKENS/SETI INSTITUTE

Fragments of the Sutter’s Mill meteorite were collected within days of falling over California on April 22. The freshness of the samples has given researchers an unusually pristine look at a rare type of space rock.

A meteorite that fell where California’s gold rush began has triggered a similar gold rush for scientists: to study one of the freshest, most unusual space rocks around.

The Sutter’s Mill meteorite turns out to be a rare, carbon-rich type known as a carbonaceous chondrite. Its insides are a jumble of different primitive space materials mashed together in a single rock.

“It’s a real hodgepodge,” says Monica Grady, a meteorite expert at the Open University in Milton Keynes, England. “It tells you that the asteroid it came from has had a very interesting history.” Grady and her colleagues describe the Sutter’s Mill find in the Dec. 21 *Science*.

On the morning of April 22, 2012, a bright fireball swept across the Nevada and northern California sky, accompanied by strong winds and a sonic boom. Weather radar detected an object disintegrating just west of the Sierra Nevada.

Meteorite hunters immediately fanned out to pick up the pieces. The first distinctive black fragment was found in a park in the town of Coloma. Peter Jenniskens, a meteor astronomer at the SETI Institute in Mountain View, Calif., soon spotted the second, crushed slightly by a car. Jenniskens even enlisted a zeppelin to fly over the region, looking for impact craters left by big pieces. (He found none.)

Over the next few months, searchers collected at least 77 meteorite fragments, together weighing nearly a kilogram. Three of those were picked up in the first two days, before rains washed over the area. That quick recovery allowed scientists, organized by Jenniskens, to start studying the rock before water altered its minerals.

“Meteorites like Sutter’s Mill represent the most primitive material of our early solar system,” says team member Qing-zhu Yin, a geochemist at the University of California, Davis.

Carbonaceous chondrites, which are thought to have delivered lots of water to the early Earth, make up less than 3 percent of known meteorites. The Sutter’s Mill specimen belongs to a subclass known as CM, rocks that are particularly rich in organic compounds.

Yin’s lab soon determined that the meteorite contains at least 78 separate chemical elements, and was born from dust and gas swirling around the newborn sun 4.567 billion years ago.

After that, things got complicated. The Sutter’s Mill meteorite was once part of a bigger asteroid, but it also contains chunks of many smaller things, just as a stew might contain pieces of beef and carrot and onion. That kind of jumbled-up rock, known as a breccia, forms as cosmic collisions pulverize an

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Less than two weeks after the Sutter's Mill meteorite showered California's Gold Country (red dot on map) with space debris, researchers were flying over the region in a zeppelin (far left) looking for craters left by large fragments. They found none.

asteroid, breaking it apart and incorporating new chunks from the impactors hitting it.

After billions of years, one of those collisions kicked off the chunk that sailed through space for some 50,000 years — as its exposure to cosmic rays suggests — before breaking up over California. It was the biggest meteorite to fall over land since another well-studied meteorite hit Sudan in 2008.

Both the Sudan and Sutter's Mill meteorites were about 4 meters wide as they hit Earth's atmosphere, but the Sutter's Mill one came in twice as fast — at nearly 29 kilometers per second. "Never before has anything been recovered from something coming in so fast," says Jenniskens. It broke apart 48 kilometers high, with the energy of 4,000 metric tons of TNT.

Its trajectory shows it was traveling on a very unusual, stretched-out orbit. Only one other space rock, which fell in 2009 in Denmark, has been seen following a similar path. Both may trace back to a family of asteroids called Eulalia, which orbit the sun in the asteroid belt between Mars and Jupiter, circling three times for every one time Jupiter orbits. On a close pass, Jupiter's gravity may have kicked Sutter's Mill on a path to hit Earth, Jenniskens says.

The rock's beat-up nature suggests that many of the Eulalia asteroids may have collided with other objects more than previously thought. More answers may be coming soon; some properties of the Sutter's Mill meteorite, like how it reflects light, are similar to the carbonaceous asteroid that Japan's Hayabusa-2 spacecraft plans to visit in 2018. NASA and the European Space Agency are also planning missions to carbon-rich asteroids in the next decade.

"Sutter's Mill might provide a rare glimpse, a prelude so to speak, of what we might find on these target asteroids," says Yin. "For me, the fun is just starting." ■

Back Story | CATCH A FALLING STAR

More than 1,000 meteorites have been collected after being seen falling to Earth. Many of them have spectacular tales attached, some of which may be too good to be true.

Ensisheim, France, 1492 In one of the first witnessed falls on record, a meteorite plunged into a wheat field, astonishing the locals. Villagers started chipping off pieces as souvenirs until a local official stopped them.

Nakhla, Egypt, 1911 Some 40 stones were seen plummeting from the sky. One reportedly hit a dog. Later analysis showed that the rocks were from Mars and had spent some time with water percolating through them.

Peekskill, N.Y., 1992 Skies over much of the eastern United States were lit up by a huge meteor. A 12-kilogram chunk of space rock blasted through the trunk of a red 1980 Chevy Malibu (right).

Tagish Lake, Canada, 2000 A bright fireball appeared, accompanied by loud sounds, over the Yukon and northern British Columbia. Meteorite hunters eventually recovered between 5 and 10 kilograms of a carbonaceous chondrite.

Lorton, Va., 2010 A doctor's practice found its late afternoon routine interrupted when a rock from space plummeted through the roof and embedded itself in three pieces in the floor of an exam room.

A car hit by a meteorite arrives for display at the Landesmuseum Oldenburg in Germany.

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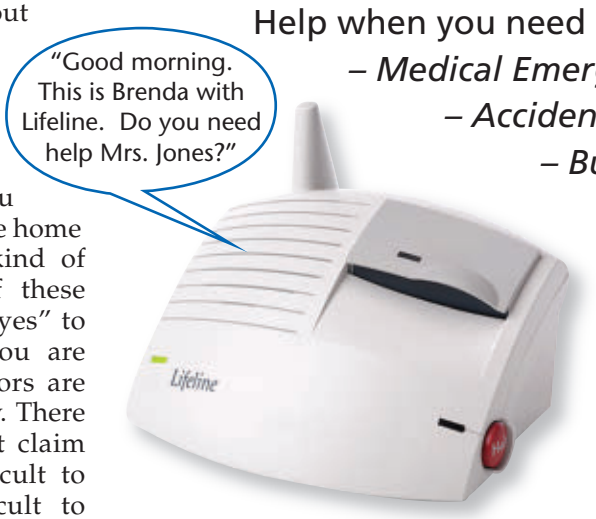

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Pressure keeps cancer in check

Confining malignant cells prevents runaway growth

By Tina Hesman Saey

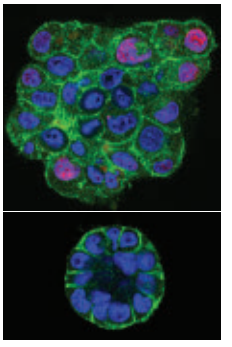
Putting the squeeze on lab-grown tumor cells makes them behave like healthy ones. The finding won't lead to treatments that crush tumors in patients, but it might lead to new drugs that keep mutated cells from growing out of control.

Breast cancer cells suspended in gel and then briefly compressed form orderly balls just like normal breast cells do, Gautham Venugopalan, an engineer and cell biologist at the University of California, Berkeley reported December 17. "We're not adding any drugs. We're not changing any genetics," Venugopalan said. "All we've done is basically kicked them and said, 'you need to be normal now.'"

The cells still carry the genetic changes that led them to become cancerous, but after the big squeeze they stop growing unchecked and behave as if they are healthy.

A protein called E-cadherin that sits on a cell's surface and helps form close bonds with neighboring cells is necessary for the return to good behavior. When Venugopalan and his colleagues added antibodies that interfere with the protein and then put the pressure on tumors, the cells stayed cancerous.

The result is surprising, said Mark LaBarge, a cell biologist at Lawrence Berkeley National Laboratory in California. Researchers had shown that growing precancerous cells in stiff three-dimensional gels brings out the cells' malignant side. So compressing cells might be expected to encourage bad behavior.



Breast cancer tumors (top) form normal-looking structures (bottom) after brief compression, researchers at the University of California, Berkeley have discovered.

Compression probably won't be used to treat cancer patients, Venugopalan said. But if the researchers can learn what pressure does to make tumors behave, they may be able to devise drugs that turn on the same processes.

The heart telltale

Engineered cardiac cells signal cellular events with a flash

By Tina Hesman Saey

A protein borrowed from Dead Sea microbes and re-engineered by researchers makes heart cells light up with every contraction. The flashing cells may offer a way to predict whether new drugs will cause heart problems in people, Harvard researchers reported December 17.

Adam Cohen and his colleagues took a protein that helps a Dead Sea microorganism harvest energy from sunlight and broke the molecule so it works only in reverse, giving off light instead of absorbing it under certain conditions. When placed in heart cells, the protein — called archaerhodopsin 3, or Arch for short — flashes dim red light when heart cells get an electrical signal to beat, Cohen reported. A different version of the Arch protein blinks blue when calcium enters the cell or is released from storage depots inside the cell to trigger heart muscle contractions.

The idea for the flashing cells came from a new field of research known as optogenetics, in which scientists use flashes of light to control the activity of nerve cells. The new technique doesn't alter the way the heart cells function; it simply allows Cohen and his colleagues to monitor the beating of human heart cells.

The researchers placed the red and blue twinkling proteins into human skin cells that had been reprogrammed to make stem cells and then were coaxed into becoming heart muscle cells. Even growing in a laboratory dish, the cells beat in time with each other. In the future, reprogrammed cells could be created from skin cells taken from people with genetic heart problems to learn more about how the condition affects heart cell function.

Splashing drugs that affect heart rate on the cells changes the way the cells beat and alters the pattern of flashes from the monitoring proteins. Cohen envisions using his flashy cells in a similar way to screen out drugs that could cause heart problems before the drugs go into clinical trials. People might one day be able to have some of their own skin cells made into dishes of heart cells to test whether certain drugs are effective.

The researchers also engineered the monitoring proteins into the hearts of zebra fish embryos, which are partially transparent, allowing Cohen and his team to see how the heart cells work in an actual organism and not just in a lab dish. Drugs can be added to the water the fish swim in to test for any toxic effects on the heart.

Putting the proteins into zebra fish is a good way to see how cells work together in a tissue, said Simon Atkinson, a cell biologist at the Indiana University School of Medicine in Indianapolis. The researchers may need to tinker with the proteins to make them brighter for studying hearts in mice, rats or other nontransparent lab animals, he said. ■

G. VENUGOPALAN/UC BERKELEY

Earth

West Antarctica warming fast

50-year temperature record shows unexpectedly rapid rise

By Alexandra Witze

A spot in the heart of the West Antarctic Ice Sheet is one of the fastest-warming places on Earth, a new study shows.

From 1958 to 2010, the average temperature at the mile-high Byrd station rose by 2.4 degrees Celsius, researchers report online December 23 in *Nature Geoscience*. That warming is at least twice what earlier, indirect studies had suggested.

"It's a big number — about as big as the most rapidly warming places elsewhere on the planet," says study coauthor David Bromwich, a polar scientist at Ohio State University in Columbus. "We were quite surprised."

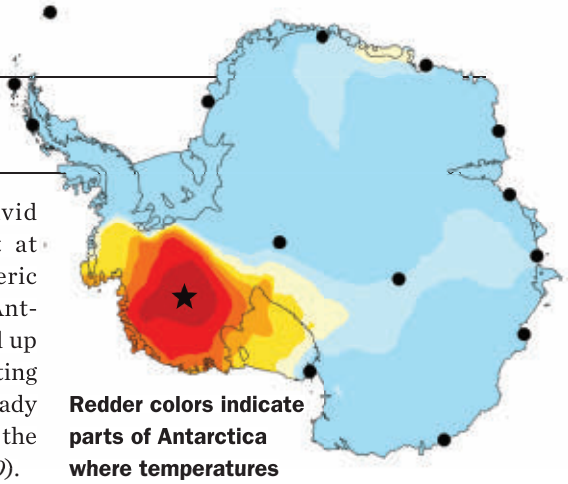
Byrd is warming fastest in winter and spring, but Bromwich and his colleagues say they also detect a statistically significant increase in summer temperature. If so, then even the frozen Antarctic interior is getting closer to melting.

"The impacts of warming here are potentially huge," says David Schneider, a paleoclimatologist at the National Center for Atmospheric Research in Boulder, Colo. West Antarctica holds far more water locked up as ice than Greenland does, and melting from both great ice sheets has already raised sea levels 11 millimeters over the past two decades (*SN: 12/29/12, p. 10*).

That's why scientists have been working to tease out whether Antarctica is warming or not. They know that parts of East Antarctica have been cooling, while places along the coast and on the Antarctic peninsula have been warming. But temperature records from the West Antarctic interior are few and far between.

The U.S. Navy established Byrd station in 1957 as part of the International Geophysical Year, and weather observers measured temperatures there until 1975. The station then fell into disuse and automated weather measurements began in 1980. Because of gaps and changes in the way weather data have been collected, many scientists had written off the Byrd record as too spotty to rely on.

But Bromwich's team wanted to take a second look, since many indirect observations — such as measurements from ice cores and holes in the ice — suggest



Redder colors indicate parts of Antarctica where temperatures track most closely with those measured at Byrd station (star). New research shows that West Antarctica is heating up faster than expected.

West Antarctica has indeed been getting warmer. Bromwich and his colleagues, including graduate student Julien Nicolas, carefully stitched together the Byrd temperature data. Then the scientists used a sophisticated computer simulation and further data analysis to fill in the missing temperature observations.

Temperatures at the station track closely with temperatures over a wide swath of West Antarctica, Bromwich says. That suggests the ice sheet may approach melting temperatures much closer to the coast, where the ice extends onto the ocean as floating ice shelves that can destabilize and break apart. Such collapses contribute to sea level rise.

FROM TOP: J. NICOLAS/OHIO STATE UNIV.; SUBGLACIAL LAKE ELLSWORTH CONSORTIUM

Polar drilling effort halts

One of three major efforts to drill into subglacial Antarctic lakes ended for the season without success as a British-led project to plumb Lake Ellsworth ground to a halt on Christmas Eve. Scientists had hoped to penetrate 3 kilometers of ice to reach the lake, where they would sample the pristine water for signs of life. But after drilling two 300-meter boreholes, engineers could not connect the two underground cavities that were meant to recirculate drilling water to the surface and keep it from contaminating the lake below. "The progress was slower than we had planned for, and we did a calculation which showed us that we didn't have enough fuel to get to the surface of the lake," team leader Martin Siegert of the University of Bristol said in a video broadcast from the ice. A Russian team penetrated Lake Vostok in February 2012 and is now working to retrieve the first water samples from the lake. A U.S.-led team set out from McMurdo station in late December on a mission to penetrate Lake Whillans. —*Alexandra Witze*

Atom & Cosmos

"This new meteorite is more like Martian crust than any previous meteorite." —CARL AGEE

Martian meteorite is one of a kind

Water-rich rock resembles known areas of Red Planet's crust

By Tanya Lewis

A recently discovered Martian meteorite that contains substantially more water than any previously found appears to be in a class by itself.

The meteorite, known as Northwest Africa 7034, formed about 2.1 billion years ago and closely matches the chemical composition of parts of the Martian surface, scientists report online January 3 in *Science*. Because of its age, the meteorite could represent a remnant of the warm, wet Mars that existed long ago.

"This new meteorite is more like Martian crust than any previous meteorite," says lead author Carl Agee, a planetary scientist at the University of New Mexico.

Found in 2011 in Morocco, NWA 7034 resembles crust in regions on Mars examined by orbiters and rovers — including rocks and soil found inside Gusev Crater by NASA's Spirit rover. Most other Martian meteorites are a poor match for the observed regions and may come from elsewhere on the surface or deeper down.

More than 100 Martian meteorites have been identified on Earth. All but one other have been part of the Shergottite, Nakhlite and Chassignite group, named for the locations where the first of each subtype was discovered. NWA 7034 has a few similarities to the SNCs. But it differs dramatically in many other respects, Agee says.

The amount of water in the rock is about 6,000 parts per million — more than 10 times the amount of water in most SNCs. The water may have come from permafrost that melted during a volcanic eruption, or possibly from liquid water on Mars' surface, Agee suggests.

To measure its water content, scientists placed the rock in an oven and heated it in stages. They also heated the sample in a vacuum and measured the different forms of hydrogen in the water vapor that formed. These results suggest the water came from Mars, the authors say.

That finding helps address a concern that the meteorite could have been contaminated by water after it landed. "It's been on Earth a very long time," says meteoriticist Derek Sears of the NASA Ames Research Center at Moffett Field, Calif, "but it doesn't look like terrestrial water."

Growing planets feed their sun

Nascent bodies funnel gas to their young parent star

By Alexandra Witze

Some 450 light-years from Earth, embryonic planets may be feeding tendrils of gas to the newborn star they orbit. The discovery helps explain how a young star can grow even as budding planets suck up much of the gas and dust around it. Without the tendrils replenishing it, the star's supply of gas would disappear in less than a year.

Jupiter and Saturn may have done something similar for the sun in its early days, 4.5 billion years ago. "This is one of the nearest examples of the birth of a solar system," says Simon Casassus, an astronomer at the University of Chile. He and his colleagues describe the finding online January 2 in *Nature*.

The star in question, HD 142527, is in the southern constellation Lupus. It's about twice the mass of the sun but far younger, only about 2 million years old. Astronomers knew it was surrounded by a swirling disk of gas and dust, which has a big clearing in it from about 10 times to 140 times the Earth-sun distance. They think a big budding planet — something like Jupiter in its very early days — might orbit its star at about 90 times the Earth-sun distance, clearing out a gap like a snowplow shoveling roads.

Casassus' team looked at this gap using the ALMA array of radio telescopes in Chile, which can detect faint emissions from gases such as carbon monoxide. The team found some of this gas drifting through the gap — probably leftover stuff that the protoplanet hadn't cleared away, Casassus says.

More intriguingly, denser gas formed several filaments stretching across the gap. These streamers are almost certainly guided and shaped by protoplanets embedded within them, Casassus says.

The filaments are faint, says University of Hawaii astronomer Jonathan Williams, but "my gut reaction is that their interpretation is probably correct and that this is an exciting result."

In this illustration, gaseous streams funnel into the young star HD 142527, fed inward by two protoplanets visible as tiny knots within the flows.

ALMA (ESO/NAOJ/NRAO), M. KORNMESSER/ESO, NICK RISINGER/SKYSURVEY.ORG

Simulations of how the gas might flow suggest not one but at least two big protoplanets surround the star. One, of around 10 Jupiter masses, probably orbits at the expected 90 times the Earth-sun distance. A second, of around 4 Jupiter masses, may orbit closer in, at around 40 times the Earth-sun distance.

Mind & Brain

For longer versions of these and other Mind & Brain stories, visit **www.sciencenews.org**

Brain tweak can alter behavior

Depressive symptoms turned on and off in mice with light

By Laura Sanders

Signs of depression can be turned on and off in mice with the flip of a switch. Activating or silencing the behavior of certain brain cells with laser light causes the animals to change their depressive behavior, two new studies find.

Although the experiments were done in rodents, the results have direct relevance to human depression, says neurologist Helen Mayberg of the Emory University School of Medicine in Atlanta. The new work may point out places in the human brain that doctors can similarly stimulate to treat depression.

The results, published online December 12 in *Nature*, relied on a technique called optogenetics, which allows scientists to control nerve cell behavior with a tiny fiber-optic light. In the studies, mice were genetically engineered to harbor nerve cell proteins that respond to light. The researchers could make certain nerve cells fire off messages by shining blue light, and quiet them by shining yellow light.

These cells, which produce the chemical messenger dopamine, nestle in a brain region called the ventral tegmental area, a spot known for handling rewards. This system may be skewed in people with depression.

One fiber-optic flash had an instant and profound effect on the mice's behavior, says psychiatrist and neuroscientist Karl Deisseroth of Stanford, who coauthored both papers. "That was pretty amazing for us."

> "Both studies are consistent in implicating dopamine in depression."
>
> PAUL KENNY

Surprisingly, the effects depend on what kind of stress the animal experiences. When mice experience low-grade chronic stress for weeks, these dopamine neurons have a straightforward role in depression-like behaviors: Crank up the cells' activity, and signs of depression go away within seconds. Hamstring the cells, though, and signs of depression, such as despair and disinterest in formerly pleasurable things (like sugar water), appear.

The second study, led by Ming-Hu Han of Mount Sinai School of Medicine in New York City, tested the same cells' role in handling more severe stress. After mice had been subjected to intense stress brought about by exposure to a dominant peer, increased light-driven activity of these dopamine neurons made the mice shrink away from another mouse a day later. These mice also didn't care for tasty sugar water as they normally would. Han and his team found that only a particular kind of nerve cell activity — a machine gun–burst of rapid firing — caused this change. A slower, steadier pattern didn't trigger the same shift.

"Both studies are consistent in implicating dopamine in depression and highlight the need for further research in this area," says neuroscientist Paul Kenny of the Scripps Research Institute in Jupiter, Fla. Especially puzzling, he adds, is the fact that dopamine's role seems to change depending on the type of stress.

In addition to studying the nerve cells in the ventral tegmental area, the researchers also explored the cells' external connections. Only the cells that send messages to a brain region called the nucleus accumbens could change depression-like symptoms, researchers found.

Drug clears Alzheimer's-like clumps

But failed human trials of similar approach fuel skepticism

By Laura Sanders

A new therapy busts up deposits of sticky plaques associated with Alzheimer's disease in the brains of mice. Further tests with the experimental drug could help settle the question of how important the plaques are to the disease, and might even lead to a treatment.

The study, described in the Dec. 6 *Neuron*, tested an antibody called mE8 in older mice genetically altered to accumulate amyloid-beta, a protein that forms plaques in the brains of people with Alzheimer's. "We removed 50 percent of the plaque," says study coauthor Ronald DeMattos of Eli Lilly and Co. in Indianapolis. "This is a big deal."

The scientists haven't looked for behavioral improvements in the mice. Nor is it clear that the drug would work the same way in people. But DeMattos and his colleagues are hopeful that the therapy will lead to new treatments for patients in later stages of Alzheimer's.

Other researchers say that busting plaques may be the wrong approach. A similar antibody recently failed to change the course of Alzheimer's disease in two large clinical trials.

"The bottom line is there's no meaningful benefit of removing plaques," says Rudolph Castellani of the University of Maryland School of Medicine.

DeMattos counters that earlier antibodies, including bapineuzumab, couldn't discriminate between free-floating A-beta and A-beta embedded in plaques. So those antibodies might have been sidetracked by the free-floating form and unable to effectively combat plaques. In contrast, the new antibody was designed to ignore free-floating A-beta and target only the plaques. This ability to hit the plaques hard may prove therapeutic, DeMattos says.

Health & Illness

64 Deaths in Australia attributed to box jellyfish stings since 1883

Zinc may treat box jellyfish stings

Creature's lethal venom strikes red blood cells, study finds

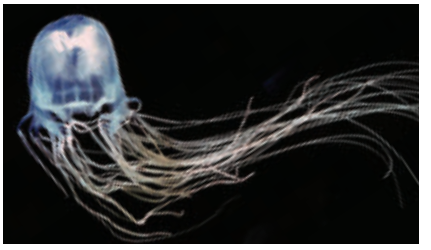
By Nathan Seppa

A zinc compound sometimes taken to treat the common cold might have a second career as emergency treatment for anyone unlucky enough to get stung by an Australian box jellyfish.

Box jellyfish (*Chironex fleckeri*), which roam the seas off northern Australia, deliver some of nature's most potent venom. Researchers have proposed that the venom attacks heart muscle cells, which would explain why sting victims sometimes suffer cardiac arrest. But in a study published online December 12 in *PLOS ONE*, Angel Yanagihara and Ralph Shohet of the University of Hawaii report that pores form in red blood cells exposed to the box jellyfish's venom.

"These are structurally sound rings of pores that are catastrophic for cells," says Yanagihara, a biochemist. Her lab experiments showed that red blood cells formed the pores within 20 minutes of exposure to the venom, triggering potassium discharge. That, she suggests, alters the delicate balance of electrolytes that govern the electrical signals that keep the heart beating. Too much potassium in the blood is fatal.

Mice given the venom had aberrant heartbeats within 90 seconds, and their hearts showed steadily deteriorating ability to contract afterward. That is consistent with potassium poisoning. But when the scientists treated eight mice with zinc gluconate after exposure to the venom, four survived more than 12 hours. Untreated mice exposed to the venom died within an average of 19 minutes. Mice receiving a standard box jellyfish antivenin died as fast as those getting no medication.



The box jellyfish delivers a sting thought to be among the world's deadliest. Zinc might counteract its effects, research conducted in mice suggests.

The zinc compound blocks assembly of the pores, stanching potassium discharge, tests in red blood cells show.

The findings offer a "plausible explanation" for the rapid death sometimes seen after box jellyfish stings, says Kenneth Winkel of the University of Melbourne in Australia.

9/11 dust tied to some cancers

Workers have higher rates of three kinds of malignancies

By Nathan Seppa

Rescue and recovery workers exposed to airborne debris from the 2001 attack on the World Trade Center in New York City are, overall, no more likely to develop cancer than unexposed people are, a new analysis of medical data shows. But a closer look at the records finds that three malignancies stand as exceptions: cancers of the thyroid and prostate and a blood cancer called multiple myeloma.

Meanwhile, bystanders and other people exposed to the dust have so far experienced no increased risk for any of 23 cancers, researchers report in the Dec. 19 *Journal of the American Medical Association*. The study was based on data from a registry that includes 55,000 New York residents exposed to the dust from the twin towers' fall.

Firefighters work in the World Trade Center rubble after the 9/11 attacks. Rates of three cancers are elevated among rescue and recovery workers.

Why three cancers showed up in workers and the other 20 didn't is unclear, says coauthor Steven Stellman, an epidemiologist at the New York City Department of Health and Mental Hygiene and Columbia University. But any cancer increase raises the concern that exposures during the rescue and months-long cleanup operation may pose future risks.

"For most cancers, the latency period is quite long," he says. "And this is very early in the process."

People who worked amid the dust include first responders, cleanup crews and barge and landfill workers who removed the rubble. By 2007 and 2008, these people showed a slightly increased risk for prostate cancer, a doubled risk of thyroid cancer and a nearly tripled risk of multiple myeloma when compared with the incidence rates in the general population of New York State.

The registry receives federal funding and is supported by the National Institute of Occupational Safety and Health. "We're encouraged to see new research and peer-reviewed studies" on the 9/11 rescue and recovery workers, says Fred Blosser, associate director for communications at NIOSH in Washington, D.C. "This kind of information is extremely useful for us in administering the health-monitoring and treatment programs."

FROM TOP: ROBERT HARTWICK; LIBRARY OF CONGRESS

Numbers

56 games | Length of Joe DiMaggio's record-holding 1941 hitting streak

Hitting streaks may be contagious

Teammates of batters on a tear also do better than usual

By Nathan Seppa

Like a popular politician with long coattails, a baseball player on a hitting streak seems to lift the performance of those around him. Teammates who play regularly with a streaking player hit at a pace above their own average during those games, a mathematical analysis shows.

"We don't prove that hitting is contagious," says study coauthor Joel Bock, an engineer at Scalaton, a software engineering firm in La Mesa, Calif. "But the data show there is something there."

Streakiness is a controversial topic. Some scientists point to a lack of evidence showing that a player can have a true "hot hand" that predicts subsequent success, such as the likelihood that a hot basketball player will make the next shot (*SN: 2/12/11, p. 26*). Even less is known about whether a hot hand can extend to others.

Bock and his colleagues analyzed the records of baseball teams on which players got at least one hit in 30 consecutive games or more. There have been 28 such streaks since 1945, starting with Tommy Holmes' 37-game tear with the Boston Braves in 1945 and ending with Dan Uggla's 33-game streak with the Atlanta Braves in 2011.

Some players really got hot. In 1969, Willie Davis of the Los Angeles Dodgers had a batting average during a 31-game hitting streak that was 165 points higher than his average for the rest of the year. Uggla averaged 184 points higher during his streak.

Applying the same calculation to teammates shows that they also hit better — by 11 points on average — during the streaks, Bock and his colleagues report December 12 in *PLOS ONE*. The researchers used only data for those teammates who averaged more than two at-bats per game during each streak.

"The results are plausible," says economist Jeremy Arkes of the Naval Postgraduate School in Monterey, Calif.

Many factors might explain contagious hitting. "There is always the chance that the pitchers have to go around the guy who is hot, and give better balls to hit to those around him," Arkes says. It's also possible that by getting on base a lot, a hot hitter distracts a pitcher, increasing the odds that the pitcher will make mistakes. And some of the effect might result just from having a hot hitter in the clubhouse. "There is extra excitement and extra purpose to playing," he says.

Life

Bioregions get a redistricting

Basis for evolutionary theory updated for 21st century

By Susan Milius

Where the wild things are A revised map of major distinctive regions of vertebrate life based on more than 20,000 species gives a new look at patterns that have intrigued evolutionary biologists for more than a century. Similar colors indicate similar mixes of animals.

With a new planetwide analysis of vertebrate life, an international team has used 21st century science to update an iconic 1876 map of Earth's zoological regions.

By incorporating data on 21,037 species of mammals, birds and amphibians, Jean-Philippe Lessard of McGill University in Montreal and his colleagues have revised a zoological map created by Alfred Russel Wallace, an oft-overlooked cofounder of the theory of evolution. Wallace's map divided Earth's landmasses into six major regions, each with its own distinctive blend of vertebrates.

Scientists have redistricted Wallace's wildlife precincts several times, mostly to fit new information on what species live where. Lessard and his colleagues, however, use not just species distributions but family tree relationships. Incorporating degrees of kinship revives the evolutionary spirit of Wallace's original map, the researchers say in the Jan. 4 *Science*.

To reevaluate Wallace's boundaries, Lessard and his colleagues used computers to divide the planet's land into squares on a grid and compared how many species from three vertebrate groups each square shared with other squares. Using massive family trees developed at the University of Copenhagen and other places, the researchers gave more weight to differences between squares if the species within were only distantly related.

The biggest change from older maps, Lessard says, stretches the old Palearctic realm of northern Eurasia into the Western Hemisphere.

The new evolutionary approach also highlights just how unusual Australian animals are, Lessard says. People think of kangaroos and other Australian mammals as odd, but it was the amphibians that launched the realm's distinctness scores to extremes.

The revision is "really the closest we've got to mapping life on Earth while considering the way it evolved," says Şerban Procheş of the University of KwaZulu-Natal in South Africa.

Repellent slime has material virtues

Hagfish excretions exhibit superior strength and flexibility

By Rachel Ehrenberg

Step aside spiders. Threads made by another creepy-crawly — the eellike hagfish — may lead to superior new fibers for parachutes, packaging and perhaps even clothing. A new study that examines the mechanical properties of threads made from hagfishes' slimy mucus finds the fibers are both strong and stretchy, and may serve as a model for creating superior new materials.

"The tensile properties approach those of spider silk, and that's very exciting," says biomaterials specialist Douglas Fudge of the University of Guelph in Canada. Synthetic fabrics such as nylon are derived from petroleum, notes Fudge, so studying hagfish threads may lead to renewable "green" materials for making all sorts of things.

Atsuko Negishi, a researcher in Fudge's lab, collected buckets of slime from Atlantic hagfish (*Myxine glutinosa*). The long, slender jawless creatures have lines of slime pores running down the sides of their bodies. When hagfish are provoked or stressed, the pores eject copious amounts of slime, which gets caught in the gills of predators.

"It's totally different from anything that we've seen in the natural world," says research scientist Vincent Zintzen of the Museum of New Zealand in Wellington.

Negishi and her colleagues anesthetized their hagfish and then stimulated them with electricity to prompt slime ejection. Then the team concentrated the slime's proteins. The researchers found they could produce threads up to 20 centimeters long by dripping the concentrated proteins onto the surface of a salty buffer solution. For reasons that aren't clear, the threads then form a film that can be drawn out and spun into a fiber, Negishi, Fudge and their colleagues report in the Nov. 12 *Biomacromolecules*.

When the threads were stretched in water, they contorted into the same molecular shape that's believed to give spider silk its strength and toughness. The researchers also discovered that hagfish threads are super stretchy, tripling in length before breaking.

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Ancient sea life cast on the rocks

Controversial study suggests early fossils were terrestrial

By Susan Milius

Some of the fossils celebrated as sea life's big breakout beyond mere soups and slimes might actually have dwelled on land, suggests a controversial new study.

Named the Ediacaran fauna after Australia's Ediacara Hills, these creatures dating from roughly 575 million to 542 million years ago mark life growing beyond the microscopic. Found in some 30 locations around the world, Ediacarans grew in disks, fronds and other fairly simple shapes with a quilted look, and paleontologists usually consider them some sort of marine creatures.

A new detailed analysis suggests that the rocks where Australian Ediacarans are found are fossilized soils, or paleosols, instead of a sea bottom, says Gregory Retallack of the University of Oregon in Eugene. The placement of fossils and tiny tubes in the rocks suggests to him that at least some of the Ediacarans actually lived in those soils instead of just washing up on them.

Retallack received "some pushback," as he calls it, for earlier proposals that Ediacarans were not sea animals but land-living lichens. With the new study, published online December 12 in *Nature*, he says he knew "people were going to be irate."

If Ediacarans do turn out to be terrestrial, the implications would go far beyond rethinking where Earth's earliest complex multicellular organisms lived, says longtime Ediacaran researcher Guy Narbonne of Queen's University in Kingston, Canada. He doesn't agree with the new interpretation, but if it is correct, it could mean that decades of studies of ancient environments were based on flawed assumptions.

Retallack specializes in analyzing ancient soils, but only in recent years has he done so in detail at the Australian geological formations that hold the Ediacarans. The rocks show soillike gradations in titanium and some other elements, he says. Patterns of uncommon forms, or isotopes, of carbon and oxygen track each other as they would in soils.

Gypsum crystals and some other nodules are junked up with internal grains of sand that Retallack would not expect if the structures had formed in water. He saw cracked and nubbly texture like old elephant skin that he would expect to see on a soil surface. The red color comes from ancient weathering instead of more recent exposure, he says.

"Unconvincing," says Shuhai Xiao of Virginia Tech in Blacksburg. He says he still thinks ocean processes could explain the Ediacaran rock details.

550-million-year-old fossils from South Australia lie in rock that might be fossilized terrestrial soil rather than seafloor mud, a new study suggests.

New contender for oldest dino

African fossil may push line back 15 million years

By Tanya Lewis

What may be the most ancient dinosaur ever found — or at least a close relative to the oldest currently known examples — could push the appearance of the beasts back to 243 million years ago.

Paleontologist Rex Parrington of the University of Cambridge in England discovered the fossil in the early 1930s in Tanzania's Ruhuhu Basin. Now, a team of scientists has taken a fresh look at *Nyasasaurus parringtoni*. It lived during the Middle Triassic period, about 10 million to 15 million years earlier than the oldest confirmed dinosaurs. The finding suggests dinosaurs evolved over a longer time than thought, the team reports in the Feb. 23 *Biology Letters*.

Only fragments of the creature's backbone and upper arm bone have been found. More are needed to determine whether the fossil is in fact the oldest dinosaur or a member of the nearest sister group.

"There's just not enough evidence to decide which of these two family trees it is," says paleontologist Stephen Brusatte of the American Museum of Natural History in New York City.

At 2 to 3 meters long and no more than a meter tall, *Nyasasaurus* was hardly a king of the beasts, says study coauthor Sterling Nesbitt, a paleontologist at the University of Washington. Nesbitt and colleagues estimate that the creature weighed about 20 to 60 kilograms.

In this artist's illustration, *Nyasasaurus parringtoni* (left) could be the oldest known dinosaur yet discovered. Plant-eating *Stenaulorhynchus* reptiles graze in the background.

FROM TOP: G. RETALLACK; © MARK WITTON/NATURAL HISTORY MUSEUM, LONDON

Humans

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Theory: survival of the fistest

Hand evolved partly for combat, researchers claim

By Erin Wayman

Ancient rumbles in the jungle might have left a lasting mark on the human hand.

The hand's proportions are such that clenching the fingers creates an effective bludgeon, a pair of researchers observes. Perhaps, they propose in the Jan. 15 *Journal of Experimental Biology*, evolution played a role in making the hand such a punishing weapon.

Other scientists are skeptical. "There's no compelling evidence that the hand evolved in this way," says Mary Marzke, a physical anthropologist at Arizona State University in Tempe. More likely, the ability to throw a good punch was just a lucky (or unlucky) result of evolving nimble hands suited to making and using tools.

A human hand (right) has shorter fingers, a shorter palm and a longer, stronger thumb than a chimpanzee hand (left). These hand proportions, which allow humans to make a fist, may have evolved in response to fistfighting.

Humans have shorter fingers, a shorter palm and a longer, stronger thumb than other apes. These features give the human hand unparalleled dexterity, and most anthropologists agree these characteristics evolved as early human ancestors began making stone tools.

David Carrier, a comparative biomechanist at the University of Utah, says aggression also shaped the hand. Although toolmaking undoubtedly influenced hand evolution, there are many ways in which an agile hand could have evolved. The fingers could have stayed long while the thumb got bigger, or while only the palm changed. But only one hand configuration allows the formation of a fist. "A clenched fist does a better job of explaining the [exact hand] proportions we have," Carrier says.

Carrier and Utah medical student Michael Morgan recruited 12 men with experience in boxing or martial arts for trials that examined the strength and stability of clenched fists. When hitting a punching bag from various angles, an open-palm slap and a fist punch exert a similar force. But because a fist has about one-third the surface area of an open hand, a punch probably does greater damage by concentrating the force over a smaller region, Carrier and Morgan suggest. A clenched fist also keeps the joints between the fingers and palm four times as stable as a hand simply folded in half, suggesting that a buttressed fist helps protect fingers from bending and breaking during a fight.

"More work needs to be done to make this a compelling argument," says Erin Marie Williams, a functional anatomist at George Washington University in Washington, D.C.

Early European farmers ate cheese

Sieves for processing milk found at ancient Polish sites

By Bruce Bower

Ceramic vessels pocked with holes have pushed the earliest evidence for cheese making back to 7,400 years ago.

Chemical signatures of milk fat in perforated pots used as strainers provide the telltale clues to cheese making, says a team led by biogeochemist Richard Evershed of the University of Bristol in England. As with similar-looking cheese strainers today, these devices — previously found at ancient farming villages in Poland — separated fat-rich milk curds from lactose-containing whey, the scientists report online December 12 in *Nature*.

Cheese making played a big part in early dairy farming, Evershed proposes. Aside from providing a reduced-lactose milk product for communities that included many individuals unable to digest lactose easily, cheese could be stored and eaten throughout the year.

Oddly, the ability to produce low-lactose cheese emerged at the same time that a gene enabling lactose digestion, and thus milk drinking, spread among European farming populations. In 2009, geneticist Yuval Itan of University College London and his colleagues calculated that the gene initially spread through Central Europe about 7,500 years ago.

It's unclear why a lactose-tolerance gene caught on so quickly if early farmers could make cheese, remarks bioarchaeologist Oliver Craig of the University of York in England. Perhaps early sieves were relatively ineffective at removing lactose from milk or were applied to cheese making by only a few communities. Lactose tolerance possibly originated in parts of North Europe and Scandinavia where no sieves have been found amid the ruins of ancient farming settlements, Craig speculates.

Evershed's group tested 50 fragments from 34 sieves for milk fat residue. Pieces of 44 cooking pots, seven bowls and 15 flasks were also analyzed. The pottery came from eight sites in Poland dating from 6,800 to 7,400 years ago.

Remnants of milk fats were identified on 15 sieve fragments, consistent with the separation of milk curds from whey during cheese making. More than half of the fragments from cooking pots displayed chemical signatures of animal fat, probably a result of cooking meat.

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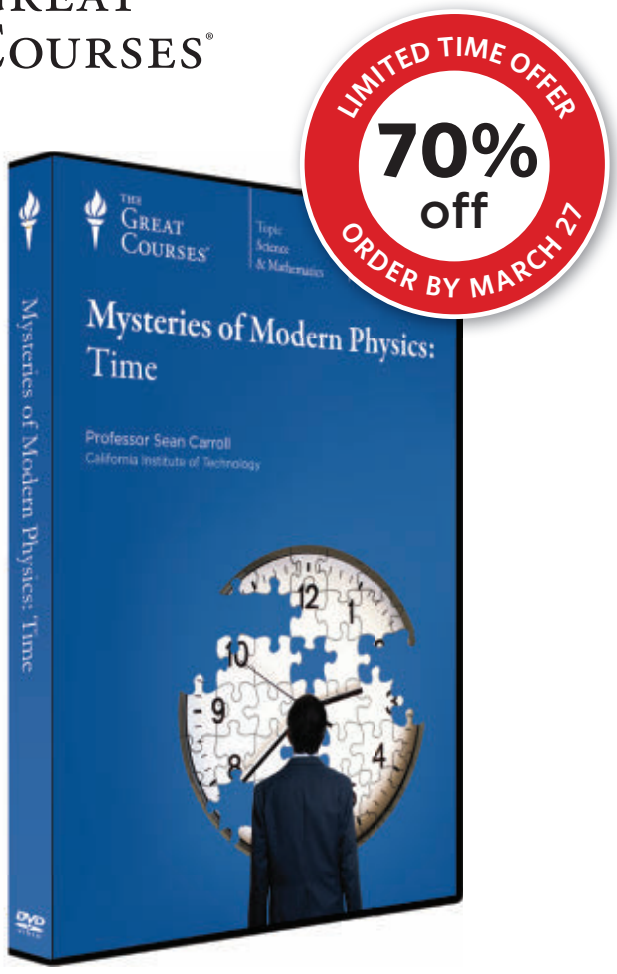

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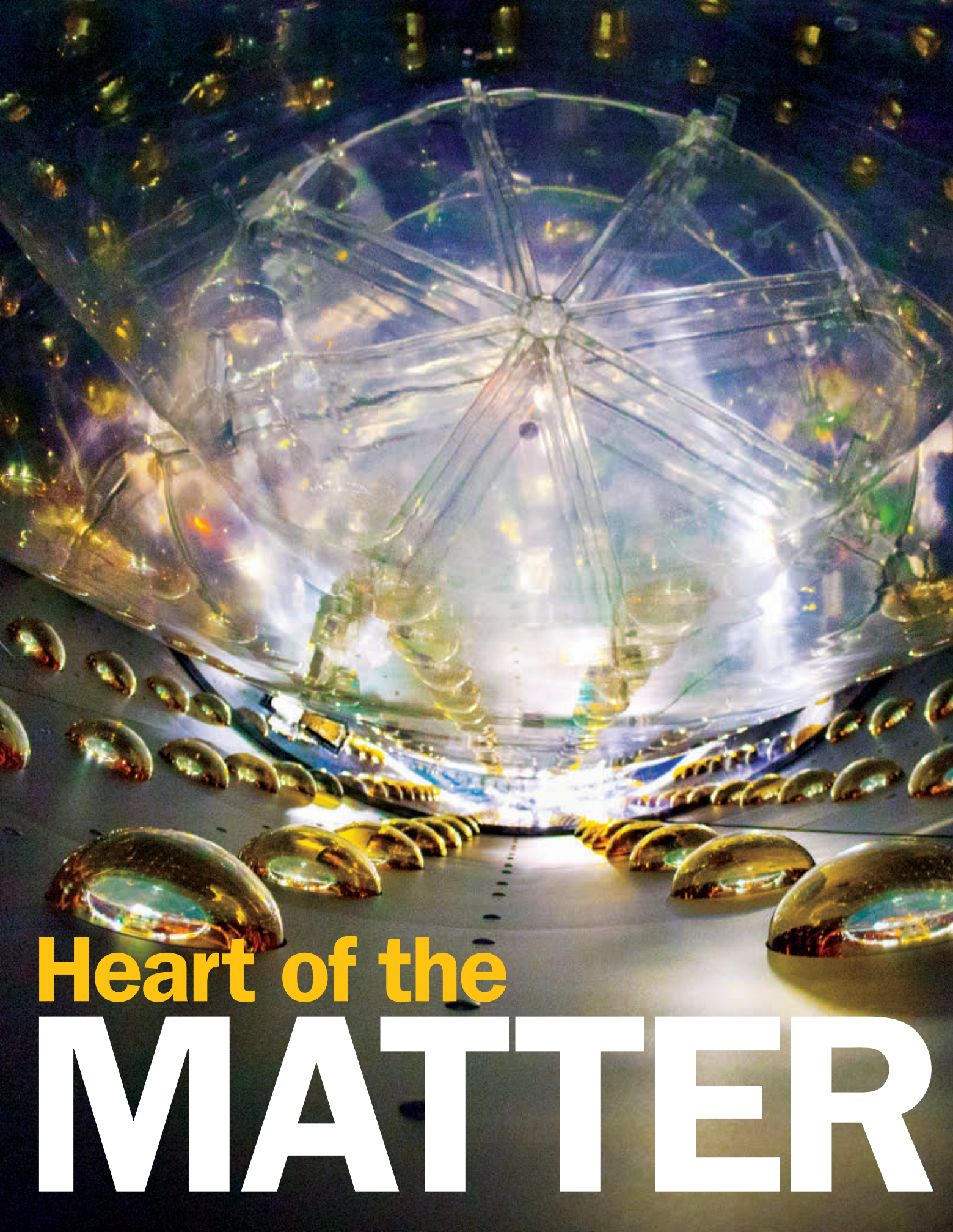
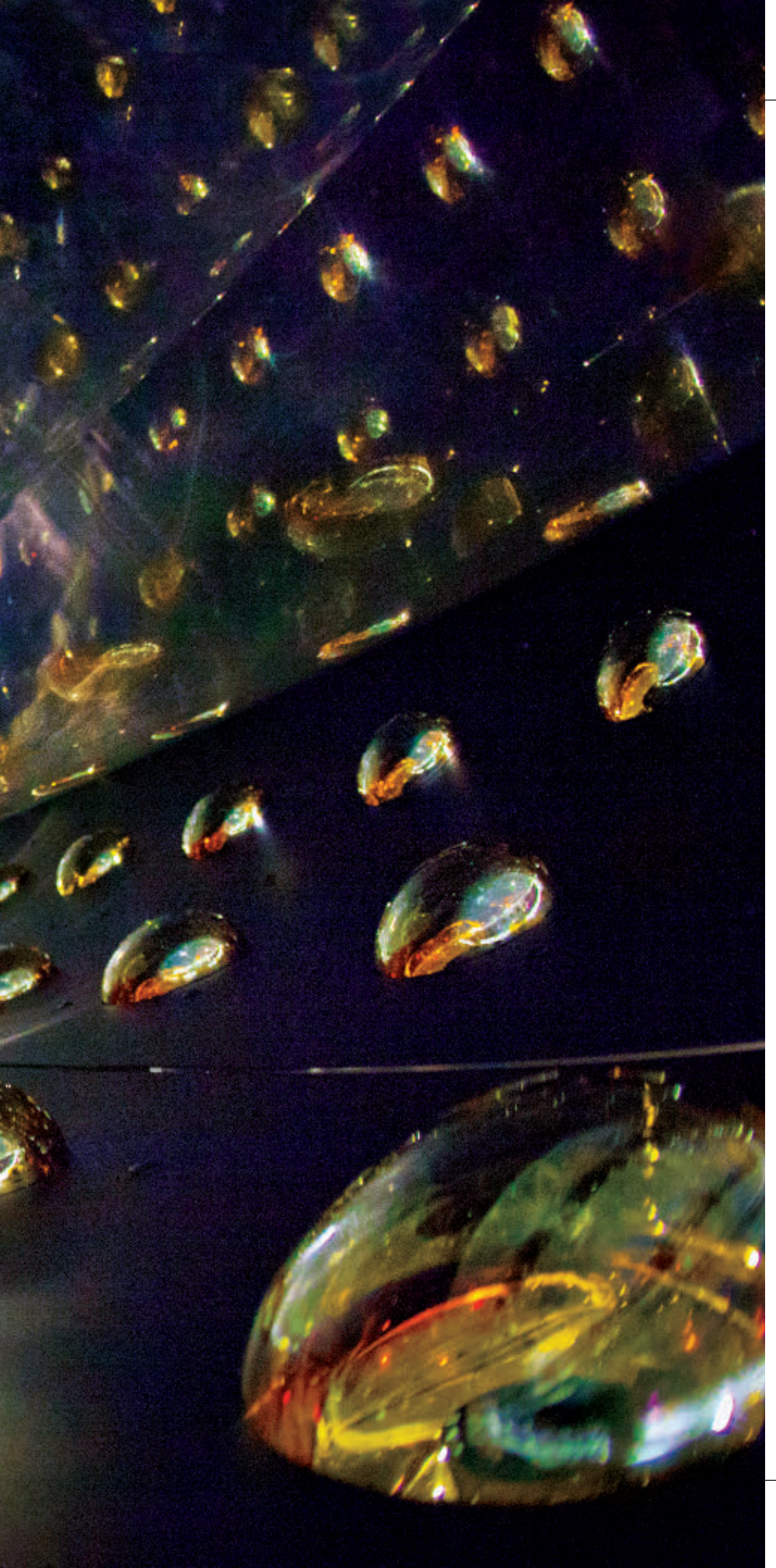


Heart of the MATTER



Neutrinos' shifty behavior might help explain why the universe has so much stuff in it

By Charles Petit

A golden age for the neutrino is dawning.

A few decades ago, these shy phantoms that flit nearly unfelt through the interstices of the universe seemed mere leftovers in the world of physics.

They outnumber all other particles of matter, whizzing away everywhere — many of them arising in droves from nuclear reactors and nucleosynthesis in stars. Their characteristics made them, to be sure, vitally important building blocks in the 1970s and '80s for theorists who put together the standard model of physics, describing how fundamental forces and particles fit together. Yet, for decades, neutrinos seemed nearly incapable of doing a lick of work. They were like clowns pouring from a circus car, entertainment for theorists but without important jobs in keeping the cosmos running smoothly.

It is about time for the neutrino to add gravitas. "When I first learned about it in the early 1950s, the neutrino had an odd role in nuclear physics, like that of a sort of crazy uncle who was not all there," physicist and science writer Jeremy Bernstein wrote in an essay in the March-April 2012 issue of *American Scientist*.

When asked how the neutrino stacks up today, he says: "It is a wonderful particle. It played an important role in the early universe. I mean, everything about it is mysterious. But back in the 1950s, nobody even gave a goddamn.

Near Daya Bay in China, detectors record the faint flashes produced when antineutrinos hit. Photomultiplier tubes (shown) pick up the signal.

ROY KALTSCHMIDT/LAWRENCE BERKELEY NATIONAL LAB

Maybe I learned about it, but nobody was studying it."

While neutrinos have been rising in mystery and thus stature for some time, their most recent big break occurred last March. It stemmed from measurements made deep inside a granite mountain not far from Hong Kong. There, an international collaboration — led by an American contingent from the Lawrence Berkeley National Laboratory in California and scientists at the Institute of High Energy Physics in Beijing — has in the last six years built some of the world's best underground detectors for neutrinos of the specific sort generated inside nuclear reactors.

The instruments sit under tens to hundreds of meters of rock to shield them from particles that would swamp the faint signals. Access is via tunnels near a tightly clustered set of three nuclear power stations along Daya Bay, each with two reactors. Together, the six reactors spew antineutrinos, the antimatter versions of neutrinos, at a rate of more than 3 billion trillion per second.

After months of sampling this subatomic flood, the collaboration (with 270 or so authors from dozens of research centers around the world) reported a far more accurate measurement of an obscure-sounding factor called a "mixing angle." Specifically, it is theta one-three or, in its mathematical representation, θ_{13}.

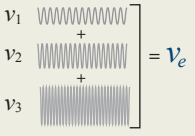
It is one of three neutrino mixing angles, and the only one that had eluded anything but fuzzy estimation. Together the mixing angles govern key aspects of an astonishingly shifty behavior that neutrinos possess.

Changing flavors One of the surprising properties of neutrinos is their ability to switch identities, or oscillate, over time. Antimatter versions also oscillate.

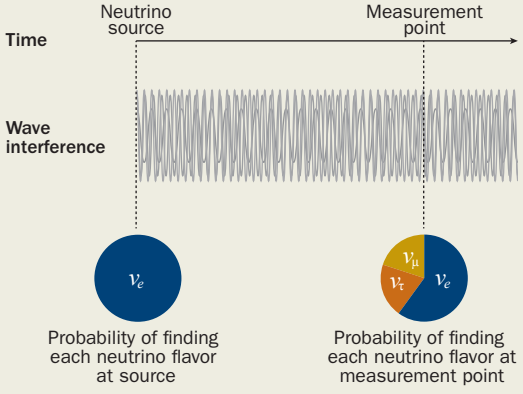
1. Neutrinos are elementary particles of matter called leptons. They come in three "flavors," each associated with a heavier lepton partner.

ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino
e electron	μ muon	τ tau

2. A neutrino flavor doesn't have any one mass, but instead exists as a combination of three mass states (electron neutrino shown).



3. As a neutrino travels from its source, the waves representing the mass states interfere, building up and canceling each other to varying degrees. Because of these wave interactions, a neutrino that starts as an electron neutrino, for example, can have a four-ninths probability of showing up as a different flavor somewhere down the line.



Reactor science Nuclear reactors near China's Daya Bay (bottom) spew antineutrinos that travel in all directions. With detectors at various locales, scientists can study the particles' basic properties. The detector halls are connected by underground tunnels (inside view at top left, and yellow lines at top right).

Measuring the mixing angle far outweighed — in the minds of physicists, if not the general public — the momentary excitement in late 2011 when a team in Italy revealed puzzling evidence that neutrinos can move a bit faster than the speed of light. That kerfuffle died fast as further scrutiny revealed it all to be an experimental error (*SN: 4/7/12, p. 9*).

As for the theta one-three result, it will take at least another decade or two of experimentation with a new generation of equipment for the full payoff. But there is the possibility for plenty of excitement.

The measurement raises hope that future tests will find, in neutrino physics, an answer to an enduring cosmic puzzle: Why is the universe dominated by matter, not antimatter? It now seems possible, in fact, that without neutrinos the universe may have lost nearly all its ordinary matter almost as soon as it was born — leaving a sea of radiation thinning and cooling forever.

Shifty particles

Confused? Hang on. Understanding the significance of the Daya Bay results requires a quick review of neutrino history.

Famed physicist Wolfgang Pauli

TOP: T. DUBÉ; BOTTOM, CLOCKWISE FROM TOP LEFT: ROY KALTSCHMIDT/LAWRENCE BERKELEY NATIONAL LAB; COURTESY OF LAWRENCE BERKELEY NATIONAL LAB; PETER & GEORGINA BOWATER/STOCK CONNECTION

dreamed these particles up in 1930, in a letter to a few colleagues addressed "Dear Radioactive Ladies and Gentlemen." The cloud chambers and other detectors of the day revealed a puzzling and variable shortage of energy in a process known as beta decay. It was first observed when atomic nuclei emit an electron. Pauli suggested that an undetected particle carried the missing energy off. The particle would have no charge and, scientists suspected, no mass. It took 26 more years just to confirm the existence of the energy smuggler.

Hard to see, indeed. Rare, no. Tens of trillions of neutrinos pass through every person on Earth every second. The type proposed by Pauli, associated with electrons, is now called the electron neutrino. Since its discovery, two more "flavors" have been confirmed: tau neutrinos and muon neutrinos, which are associated with two unstable partner particles that, like electrons, belong to the lepton family of elementary particles. Each neutrino flavor, as with other elementary particles, comes in an antimatter version, too. Recent rumblings have some theorists thinking about the possibility of a fourth neutrino, so incapable of coupling with other particles that it is called the sterile neutrino (*SN Online: 6/1/10*). Such a particle would point to physics beyond the standard model, but for now remains a big question mark.

Physicists have also been surprised by overwhelming evidence in the last 10 to 20 years that neutrinos have a smidgen of mass. The exact heft for each flavor is keenly sought, but none is large. Efforts thus far reveal that the neutrinos have different masses, and that one is markedly distinct from the other two, but no one knows which one it is. Whatever the masses, each appears to be less than a fraction of a millionth that of the electron and under a billionth that of the proton.

Nothing with mass can travel at the speed of light. But featherweight neutrinos come close. A neutrino with the typical oomph of those made in nuclear reactors would have a velocity that differs from the speed of light by only one part in 10^{20}, says Zoltan Ligeti, a theoretical physicist at Lawrence Berkeley National Lab. "A light-year is 10^{16} meters. So a neutrino traveling a light-year would be 0.1 millimeters behind a photon" on the same trek in a vacuum, he concluded.

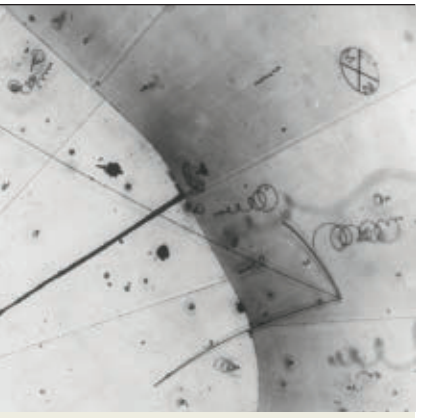
Other than through their tiny gravitational pull, neutrinos react with other matter only via the second-feeblest force in nature — called, for good reason, the weak interaction. Once in a long while, a neutrino may hit a quark inside a proton or similar particle just right and trigger a spray of debris of other particles. But neutrinos may also go through light-years of solid lead without leaving a trace. Many that were spawned in the Big Bang still zoom on today. Detecting them continues to be maddeningly difficult, which is why instruments are usually buried deep in ice caps, under the sea, far underground — or inside mountains.

Finally, most peculiarly and most at the heart of the matter, neutrinos are geniuses of disguise. Each variety has in its nature a tincture of the other kinds of neutrino. An electron neutrino may masquerade as a muon neutrino for a while, then revert. In the 1960s, many physicists feared the sun's thermonuclear fires were ebbing — a serious matter for Earth's habitability. Two-thirds of the expected neutrinos could not be detected. Eventually, physicists concluded that electron neutrinos were changing into tau and muon garb, equivalent to invisibility cloaks to which the original detector was blind.

Physicists refer to this identity-switching as oscillation. It is not unknown among fundamental particles; quarks and particles called kaons do it too. Only particles with mass, if only a bit, can oscillate this way. For years since the discovery, work at labs around the world has accumulated data on how and when neutrinos oscillate. The hope: to understand the full nature of these unruly characters.

The right angle

Daya Bay's six detectors in three halls spent 55 days in late 2011 and early 2012 counting antineutrinos. An array of photomultiplier tubes, essentially light meters, surrounded six transparent, acrylic-walled chambers filled with an organic fluid scintillator that fluoresces when struck by particles. The light meters recorded flashes as the antineutrinos scored the occasional hit. The daily harvest was about 70 neutrinos, out of the uncounted zillions that flew



SCIENCE SOURCE

A long trek

Eight decades on, scientists are still struggling to understand the nuances of neutrino behavior.

1930 Wolfgang Pauli proposes a new neutral particle to explain missing energy in beta decay.

1933 Enrico Fermi incorporates the "neutrino" into beta decay equations.

1956 Clyde Cowan and Frederick Reines report the first experimental evidence for neutrinos. A later image (above) shows an invisible neutrino striking a proton to create three straight tracks in a hydrogen bubble chamber.

1957 Italian physicist Bruno Pontecorvo formulates a theory of neutrino oscillations.

1962 Experimental tests show that at least two types of neutrino exist.

1968 Neutrinos are detected coming from the sun, but there are far fewer than theories predict.

1975 A new lepton, tau, is discovered, suggesting a third neutrino flavor. It is observed much later.

1998 Super-Kamiokande experiment offers strong evidence that neutrinos oscillate (and have mass). Oscillations later resolve the solar neutrino problem.

2012 Daya Bay's theta one-three result suggests future tests may shed light on the matter-antimatter puzzle.

through without detection. But more crucial, the far detectors, 1,500 meters or so from the line of reactors, saw about 6 percent fewer electron antineutrinos than might be expected given the measurements from the closer detectors.

The deficit measured at this distance fits with a theta one-three mixing angle of about 8.8 degrees. This measure is not a physical angle but appears in the plots of equations that physicists use to assess how packets of quantum mechanical waves slosh about in abstract spaces, pushing the probabilities up and down that a neutrino will be caught as one flavor or another.

Physicist Bill Edwards, U.S. coleader of the Daya Bay collaboration, says of the theta one-three result: "We nailed it. There is not much doubt now of its value to a very small uncertainty."

Not only that, it is larger than had been expected, which means that key behaviors of neutrinos should now be easier to sift out. "This is an important result because for the first time we have determined with certainty that the mixing angle theta one-three is not zero. We had indications but nothing, until now, that told us conclusively," says Kam-Biu Luk, another Berkeley physicist and Edwards' codirector for the U.S. side of the Daya Bay experiment. A zero would be bad news, wreaking havoc in key equations and making the full suite of neutrino behavior much harder to observe.

Boris Kayser, a theorist at the Fermi National Accelerator Laboratory in Batavia, Ill., agrees. "This is wonderful news," he says. "There are no huge engineering hurdles to go."

With rough values of all three mixing angles now in hand, science takes a key step toward learning what happened in the first few moments after the Big Bang more than 13 billion years ago that left the universe dominated by matter rather than antimatter. Had the two kinds been neatly balanced they may, in a short time, have annihilated one another. That means no stars, no planets, nobody.

The Daya Bay result, and neutrinos' ascendancy more generally, is historic for another reason — national pride. It marks a new stature for China in elite, basic science. In fact, it is payoff for a host of Asian nations investing heavily in neutrino science and joining Europe, North America and Japan in the front row.

The road is open for a long list of experiments needed to further define the behavior of neutrinos.

A report in *Science* on the announcement declared that the measurement "puts Chinese particle physics on the map." Many other physicists agree, but China's project officials don't brag out loud to that extent. Yifang Wang, director of the Institute for High Energy Physics in Beijing and overseer of the 150 Chinese physicists and engineers working on it, says that the experiment is important but China's rise is too big a concept to be achieved by just one result.

Last April, close on the heels of Daya Bay, the Korean-based Reactor Experiment for Neutrino Oscillation, or RENO, reported much the same result from tests near a six-reactor complex of its own. Japan too might have been in the running, but the neutrino source for its famed Super-Kamiokande detector had to be shut down for repairs after the 2011 earthquake devastated the nation's northeast. Within five years another Asian nation expects to join those with front-rank facilities: The $300 million India-based Neutrino Observatory, or INO, is about to start tunneling into a mountain near that nation's southern tip, creating India's signature facility in basic physics.

Physics not magic

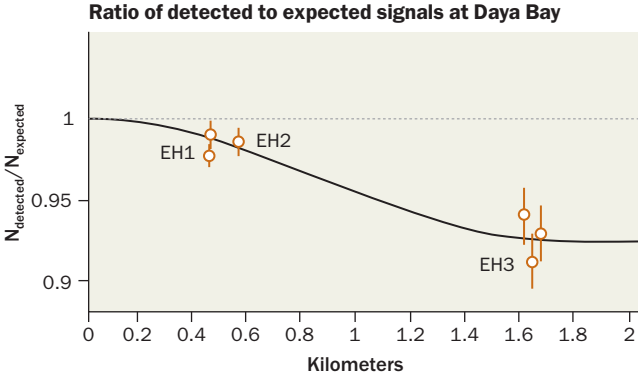
For neutrino hunters around the world, the Daya Bay results are a bright green light to step up the chase. The road is open for a long list of experiments needed to further define the behavior of neutrinos on the rare occasion that they manage to interact with matter. After that will come experiments to compare matter interactions with antimatter ones.

If there is a difference, it will bolster a key role for another related but distinct family of exotic, very massive neutrinos that some theorists believe were in the stew of dense, hot radiation and particles present during the first few trillionths of the second after the Big Bang. Such conditions are impossible to re-create in any conceivable machine. But theory says such super-neutrinos could have, briefly, interacted vigorously and as equals with the quark stew or budding protons around them.

If today's family of neutrinos discriminates against antimatter, it stands to reason that the heavyweights of the ultimate yore may have done the same. Neutrinos may have been a little like flawed magicians' hats that do a slightly better job of turning white rabbits into brown rabbits than the other way around. After a few hundred rounds of presto-shazam, brown rabbits would vastly outnumber white ones. Ditto for matter over antimatter. It wouldn't have been magic, but physics. And because matter and antimatter mutually annihilate, plenty of matter would have been left when the dust settled.

Signal drop-off

Researchers at the Daya Bay experiment measured a drop in electron antineutrinos between two nearby experimental halls and a far detector hall. The deficit (shown) suggests future experiments can uncover key neutrino properties.



SOURCE: F.P. AN *ET AL*/DAYA BAY COLLABORATION

That's the hypothesis. Whether a facility in the United States or Europe, or one in Asia, actually gets to testing it first is hard to guess.

In the near term, efforts in the United States are likely to maintain vigor at Fermilab, filling the gap left by the shutdown of the huge Tevatron particle collider that for decades gave the lab its public face (*SN: 9/24/11, p. 22*). Workers are upgrading neutrino-generating equipment in the lab's main injector storage ring — originally built to feed protons and antiprotons into the Tevatron and a major accelerator by itself. "We call it a superbeam, a muon neutrino superbeam," says Steve Brice, head of neutrino experiments at Fermilab.

The beam aims toward detection facilities more than 700 kilometers to the northwest. One detector is at an existing complex, the MINOS or Main Injector Neutrino Oscillation Search, in the deep Soudan mine in northern Minnesota. It has spent years measuring the disappearance rate of Fermilab's muon neutrinos. Under construction about 80 kilometers away, near Ash River, is a mammoth new detector for the Nova experiment (pronounced Nova, even though the letter "v" is written as a Greek nu, or ν, physics shorthand for neutrino). It is to have a mineral oil–filled 14,000-metric-ton detector touted as the biggest plastic structure ever built (about 15 meters high and wide and just under 70 meters long). The detector will be sensitive to electron neutrinos, the flavor into which Fermilab's muon neutrinos presumably oscillate.

From this should come refined measurement of the mixing angle theta one-three. Eventually, the Long-Baseline Neutrino Experiment will sample Fermilab's neutrino beam from even farther out, more than 1,200 kilometers away at South Dakota's underground Homestake Mine neutrino facility. With the right targets, it may be able to test whether the neutrinos in the beam interact differently with matter and antimatter.

U.S. budget pressures have already nearly axed Fermilab's Long-Baseline experiment — saved after a desperate appeal by its leaders — and may do so still as further fiscal cycles put on the squeeze. Some think Asia's big programs are front-runners. "My bet is the Japanese will be the first to build a neutrino factory that can do the job," says Nobelist and Boston University physicist Sheldon Lee Glashow.

And India's new observatory, says its leader Naba K. Mondal of the Tata Institute of Fundamental Research in Mumbai, will be at about the right distance to detect neutrinos shot from either Japan or Europe and to spot any preference for matter over antimatter.

Whoever succeeds, the case may build for primordial, massive neutrinos as the agents that culled antimatter from the early universe. Quite a change in neutrino respectability from the days when their contemporary, lightweight kin were dismissed as the crazy uncles of physics.

Even crazy uncles may have interesting family lore to share. ■

PETER GINTER

A global endeavor Ongoing and future neutrino experiments around the world seek to pin down the properties of these shape-shifters.

China
Not far from Hong Kong, along Daya Bay, researchers are studying neutrinos spit from six nuclear reactors. The Daya Bay Reactor Neutrino Experiment, an equal partnership between the United States and China, recently made the best measure of the theta one-three mixing angle.

South Korea
Shortly after the Daya Bay experiment announced its results, the Reactor Experiment for Neutrino Oscillation put out a confirmation. The Korean experiment is set up in much the same way as China's Daya Bay experiment.

India
The India-based Neutrino Observatory, or INO, aims to build a large underground laboratory in Tamil Nadu, in the southernmost part of India. The goal is to study neutrinos from natural and laboratory sources with an iron calorimeter detector.

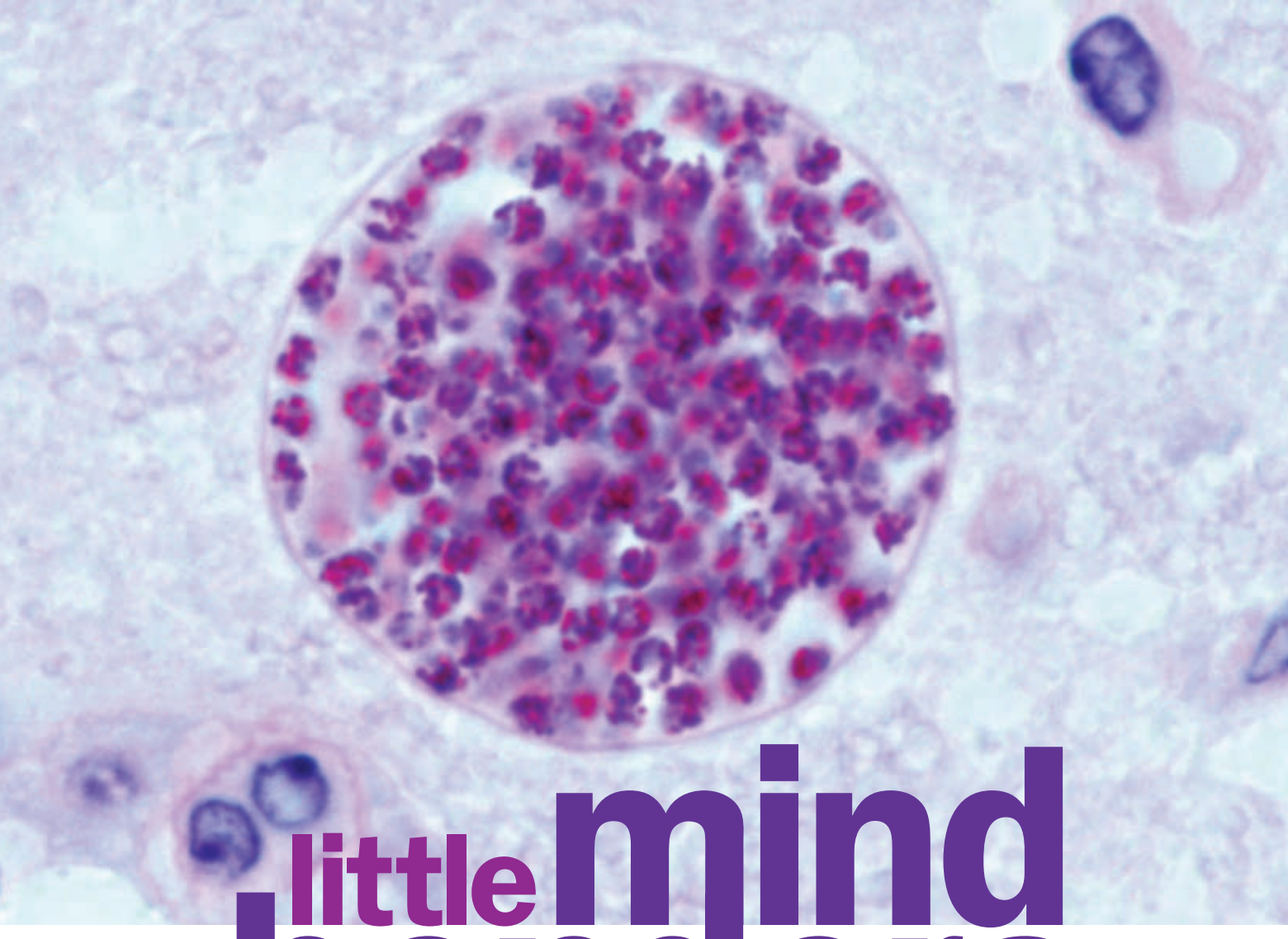
France
Chooz Nuclear Power Plant serves as a neutrino source for the Double Chooz neutrino oscillation experiment. This experiment had hinted at a nonzero value for theta one-three in November 2011.

Japan
Buried a kilometer underground, Super-Kamiokande is a huge steel tank with ultrapure water that detects Cherenkov radiation produced when neutrinos interact with water atoms. Super-K acts as a far detector for the T2K experiment, which investigates neutrino oscillations.

United States
Neutrinos produced at a Fermilab beamline (horn for focusing the beam shown above) are shot in a northwest direction toward neutrino detectors. MINOS relies on a near detector and another in northern Minnesota. The Nova detector, in the works, will be even farther away.

Explore more

- Find out more about Fermilab's Long-Baseline experiment and related neutrino projects: lbne.fnal.gov



JITENDER P. DUBEY, CDC

little mind benders

Parasites that sneak into the brain may alter your behavior and health

By Susan Milius

Imagining tiny creatures infiltrating human brains is creepy enough. But Marion Vittecoq knows she has been invaded. Her inner companions may be just hanging out — or they may be subtly changing her personality, manipulating her behavior or altering her risk of disease. Yet she doesn't sound particularly upset.

Not once in the course of a phone conversation and many e-mails did Vittecoq recommend wearing tinfoil hats or mention mind control by the CIA, the United Nations or little green men beaming rays from the moons of Uranus. She studies the ecology of parasites, especially the one-celled *Toxoplasma gondii,* which coincidentally is the creature that has invaded her brain.

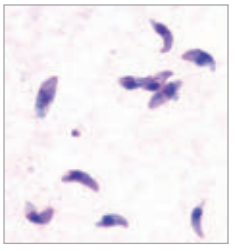
She doesn't see it as an extraordinary intrusion. The parasite has wormed its way into an estimated one-third of people on the planet. In France, where Vittecoq works at both a CNRS national research lab in Montpellier and the Tour du Valat research center in Arles, nearly one-third to about one-half of adults carry hitchhiking *T. gondii*. CNRS research colleague Frédéric Thomas is also infected, and also doesn't fret about it.

In the United States, almost one in four residents over the age of 12 has the infection. In other parts of the world, rates are as high as 95 percent. An unlucky minority of these infected people become quite ill. Most, however, don't even know that their muscles and brains carry the parasite.

What exactly *T. gondii* is doing while

***T. gondii* parasites hunkered down in a brain cyst (left, in a mouse) can keep an infection alive. Before retreating into cysts, the parasites exist in a banana-shaped form (below).**

it lurks in so many people is an important question for public health. It's also an alluringly spooky question. "Where science meets science fiction" is how Michael Dickinson of the University of Washington in Seattle describes studies of parasites that hack into their hosts' nervous systems. *The Journal of Experimental Biology*, where Dickinson serves as an editor, dedicated its Jan. 1 issue to this emerging field, dubbed "neuroparasitology." In those pages and elsewhere, clues to *T. gondii*'s bizarre biology are emerging. And growing evidence suggests that the hidden parasite may have visible effects.



Studies comparing the infected and the noninfected raise the possibility that the parasite tweaks a person's personality or ups the risk of suicide attempts, brain cancer and schizophrenia. Studies in people even report links between *T. gondii* and traffic accidents, greater odds of having sons than daughters, extra height and unusual opinions about the smell of urine.

If so much of what people do turns out to have a touch of parasite about it, then the notion of normal human behavior may have to change. What is "routine" for people might need to encompass not just the activities of a *Homo sapiens* by itself, but also the doings of *Homo sapiens* as a walking ecosystem where microbes and mammal intermingle.

Meet the parasite

Ending up in this walking ecosystem is a bit of bad luck for *T. gondii*.

The organism is a cat parasite and can have sex only within cells in the gut of some kind of feline. Matings there produce offspring protected in toughened structures called oocysts, which the cat excretes into soil and water, and which ready themselves within a few days to start a new generation. Oocysts, like space capsules, protect the cells tucked within for months. To flourish, though, parasites need the temperature-controlled, safe, nutrient-rich paradise of a live warm-blooded vertebrate.

If a cat swallows one of the infectious *T. gondii* oocysts, hurray for the parasite. The sexual phase can repeat. But if, say, a person takes in an oocyst, from contaminated food or from a flawed litter box–cleaning technique, *T. gondii* can still cope. It changes into a form that repeatedly clones itself, known as a tachyzoite. "It's a lovely banana-shaped organism, and it glides," says parasitologist Christopher Hunter of the School of Veterinary Medicine at the University of Pennsylvania.

Tachyzoites and other invading *T. gondii* can bring a human several weeks of low-grade, achy, flulike discomfort, as well as eye infections that can scar the retina. New infections in mothers-to-be can raise the risk of miscarriages as well as of developmental damage to the baby. People with suppressed immune systems are especially vulnerable and can die from untreated infections.

A healthy human immune system doesn't necessarily eliminate the banana-clone army but typically drives it to retreat. Under full attack, the parasite wraps itself in tiny bomb-shelter cysts, mostly in the muscle and brain tissues of its host. (Not many parasites can safecrack their way into the well-protected brain, but once there, they enjoy a respite from the full strength of the host immune system.)

Inside these cysts, *T. gondii* keep the cloning, and thus the infection, going in slow motion for years, ready to jump to any new host if given a chance. These cysts are the *T. gondii* form accused of mind control and other mind-jacking stunts in affected humans.

People are far from the only noncats where *T. gondii* can make do. The parasite can infect grizzly bears, bison, chinchillas, elephants, domestic goats and sheep, koalas, New World monkeys, barred owls, pigeons, pronghorn, sea lions, wombats and many more species. Such a vast range of immune systems to evade shows the virtuosity of the parasites. "How do they do that?" Hunter marvels.

Part of the answer, he says, is a Swiss army knife approach to breaking through vertebrate immune defenses. *T. gondii* has accumulated plenty of molecular tools, such as proteins to inject into host cells, Hunter noted in November in *Nature Reviews Microbiology*. Regardless of what bird or mammal swallows a parasite, *T. gondii* probably has something in its repertoire that will help it make a new home. "If I eat a pig, I get infected," Hunter says. "If the pig eats me, the pig gets infected."

Masters of lurking

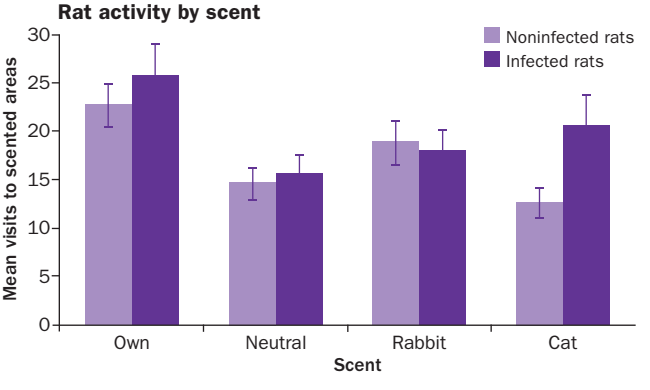
Whether *Toxoplasma* cysts manipulate pigs or parasitologists is still an open question. But research on the possibility was inspired in part by the very odd things that lurking cysts do to rats.

Biologists first discovered *T. gondii* in the early 1900s, but for decades

Pee appeal

Early research found that *T. gondii*–infected rats spent more time around cat urine (but not other urine) than non-infected rats. Ongoing work suggests that the parasite makes the typically fear-inducing scent appealing.

SOURCE: M. BERDOY, J.P WEBSTER, D.W. MACDONALD/ *PROC. R. SOC. LOND. B* 2000



DPDX, LABORATORY IDENTIFICATION OF PARASITES OF PUBLIC HEALTH CONCERN/CDC

researchers largely dismissed the parasite's stealthy cysts as inactive, irrelevant grit in the brain. It wasn't until the mid-1990s that several lines of research took off exploring how slow-going infections might be very relevant. Joanne P. Webster, now at Imperial College London, and her colleagues have since built a case that rats with a brainful of supposedly harmless cysts behave almost as if trying to become cat food.

A pounce and gulp from a cat is about the best thing that can happen to a parasite, but cat horror runs deep in rats. Even lab rats whose ancestors have not encountered cats for hundreds of generations normally avoid a catty scent.

When infected with *T. gondii*, however, rats became more active, a risk factor in itself for encountering a predator. They largely lost their reluctance to venture into test areas reeking of cat urine, and some of the infected rats actually spent more time in these urine-perfumed areas than in untainted refuges, Webster and colleagues reported in 2000. The parasite may possess an evolutionary trick that turns fear into a fatal attraction.

This upside-down behavior doesn't come from a general interest in excretions. Urine from rabbits, as useless a species for parasite sex as rats themselves, doesn't hold noticeable allure. Nor does urine from mink and dogs, other rat predators of limited benefit to the parasite.

What's more, rat brains don't malfunction in these ways when infected with just any brain parasite. Rats dosed with *Leptospira*, which doesn't need cat innards for sex, aren't driven to reckless activity by a whiff of cat.

Toxoplasma cysts do something fairly specific, says Robert Sapolsky of Stanford University. Rats infected with *T. gondii* still learn to avoid scary things, such as lab-generated electric shocks to the feet, he and his colleagues have found. And in 2011 in *PLOS ONE*, the team reported that, at the scent of a cat, the activity in the cyst-riddled brain of a male rat partially shifts from a nerve pathway that typically responds to scary scents to a chain of nerves that often sizzles at the scent of a female. The parasites seem to be rewiring "oh no!" into "oh, honey!"

Sapolsky wonders, too, about infected females, who also show interest in cat odors. "My bet," he says, "is that *Toxo* knows how to make cat odors smell like babies to females."

Neurochemical work is yielding clues to how a one-celled parasite creates such subtle effects. In parasite-manipulation studies, Webster discovered that infected rodents were less likely to get stupid about cats if dosed with a drug called haloperidol. The drug blocks a portion of brain cells' molecular docking stations for the chemical messenger dopamine. *T. gondii*, Webster hypothesized, may be brainwashing rats with excess dopamine.

Unexpected evidence for this hypothesis turned up in 2009, as researchers reveled in the recently described genome of *T. gondii*. Though not thinking about brain messenger chemicals at the time (*Toxo* doesn't have a brain), molecular parasitologist Glenn McConkey of the University of Leeds in England and his colleagues discovered genetic instructions for the manufacture of an enzyme that animals use to make dopamine.

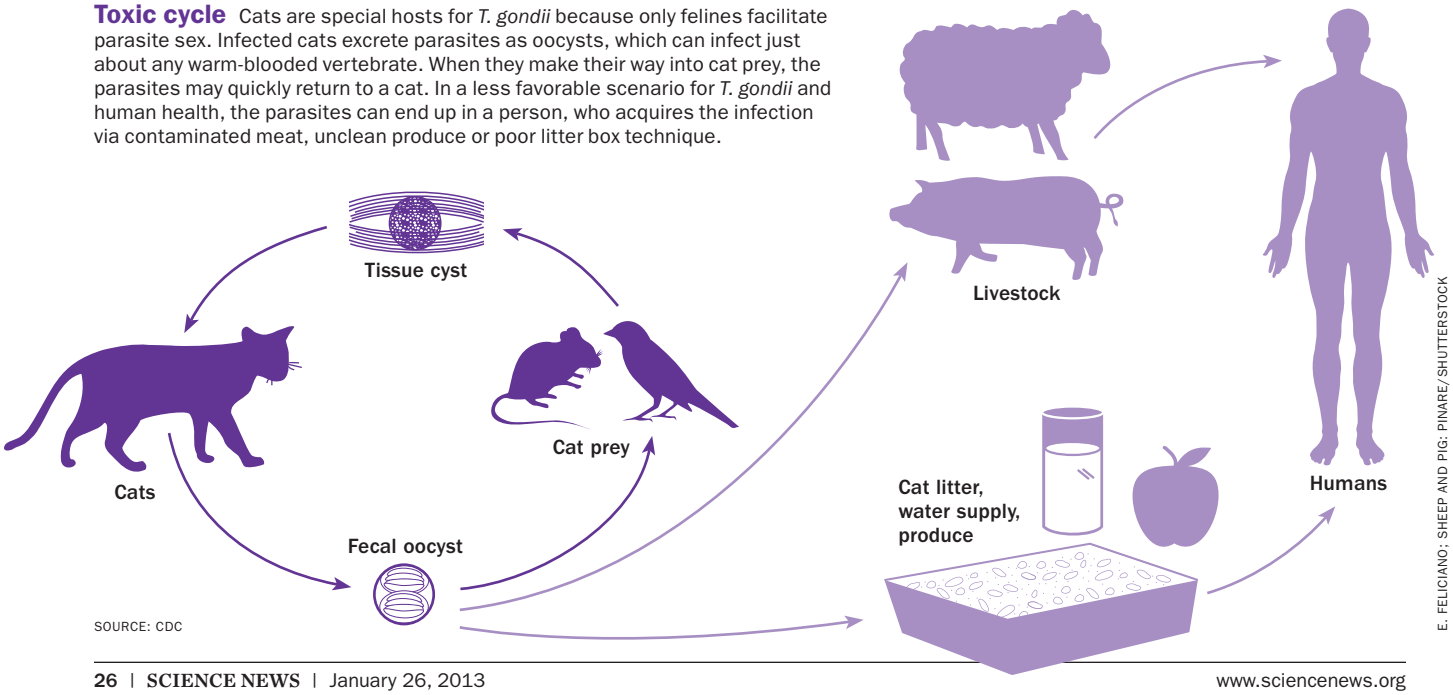
Before the discovery, no one had imagined that a single-celled creature might have such a genetic tool. But the gene fits the scenario of *T. gondii* changing the brain's usual supply of transmitter compounds.

McConkey, Webster and colleagues reported more evidence for the hypothesis in 2011. Brain tissue in infected rodents abounds in dopamine, as do parasite cysts growing in lab dishes full of rodent nerve cells.

Brain changer

If *T. gondii* cysts can manipulate rats so deftly, biologists wonder what the parasites might do inside a human brain.

Toxic cycle Cats are special hosts for *T. gondii* because only felines facilitate parasite sex. Infected cats excrete parasites as oocysts, which can infect just about any warm-blooded vertebrate. When they make their way into cat prey, the parasites may quickly return to a cat. In a less favorable scenario for *T. gondii* and human health, the parasites can end up in a person, who acquires the infection via contaminated meat, unclean produce or poor litter box technique.



SOURCE: CDC

E. FELICIANO; SHEEP AND PIG: PINARE/SHUTTERSTOCK

Longtime *T. gondii* researcher Jaroslav Flegr of Charles University in Prague has gone so far as to test whether cysts can make people more favorably inclined toward the odor of domestic cat urine. For men: yes, a bit, he and his colleagues reported in 2011. For infected women, the researchers discerned the opposite effect: a greater distaste. (In the tests, Flegr diluted the urine so none of the student volunteers could guess what they were sniffing.)

It would be a stretch to suggest that evolution might have favored parasite adaptations that do no more than make infected people like cat urine. Such a shift probably would not help the parasite find a preferred host, as it would not greatly increase the chances of cats dining on people. More likely, any voodoo that *T. gondii* exercises in the human brain is a side effect of capacities that benefit the parasite in other hosts.

Arguably, the eeriest of such effects in humans, if it proves real, is personality change caused by cysts that settle in for life and then seep chemicals like dopamine into the brain. Flegr, who has been administering personality tests to infected people for almost two decades, first became curious about the possibility when he discovered that *T. gondii* lurks in him. He devised his first questionnaire on parasite-induced trends by reflecting on what puzzled him about his own personality.

To keep people from gaming his *Toxoplasma* questions, Flegr melded them with a personality test widely used at the time. The questions he made up didn't produce any interesting results, but the supposed distracter questions did. Since those first surveys, he has turned to a commonly used questionnaire that evaluates five broad traits. The new tests, he says, suggest that infected people tend to be more extroverted but less conscientious than people without the lurkers.

"It's a small effect," Flegr says. *T. gondii* infection explains only a tiny portion of the personality differences he has measured among people.

A much stronger and more worrying connection concerns a person's risk for traffic accidents. Infected people have more than double the accident risk of noninfected people, he says. Parasite infection appears to slow reaction time.

Over the years, Flegr has also tested for links between *T. gondii* and lack of diplomacy, attitudes toward hypnosis, reduced fear of snakes and big spiders, and inclination to (metaphorically) stir up hornets' nests. In all his testing, he attends to any small leanings he may find. Like any evolutionary biologist, Flegr knows that slight differences can eventually have noticeable effects.

Sapolsky notes that so far Flegr and his collaborators have pushed forward this type of personality research largely on their own. "Flegr's findings are fascinating, immensely provocative," Sapolsky says. "In general, the effects seem quite subtle, which means it is particularly important for them to be replicated."

Recently, Teodor Postolache of the University of Maryland School of Medicine in Baltimore and his colleagues have been following up with a version of the work. Postolache won't be ready to discuss his results until at least the spring, he says. But he will say that his investigations add an important step: screening out potential study volunteers with mental troubles such as depression or personality disorders.

Parasite perils

Postolache and others suspect *T. gondii* parasites may cause changes more serious than subtle personality shifts, possibly undermining health in sneaky, long-term ways. Infected women have a higher risk of self-directed violence, including attempted and completed suicide, than do women without the parasite, Postolache's team reported in November in *JAMA Psychiatry*. Postolache's earlier studies had suggested a boosted risk with infection, but this new analysis of nearly 46,000 women in Denmark had the unusual strength of establishing which women were infected before the violence occurred. When Postolache isolated the records for women with no previous history of mental health problems, the link got even stronger. He is careful to offer a reminder, though, that finding a link is not the same as identifying a cause.

Human hijacking

If *T. gondii* can manipulate rats, why not humans? Biologist Jaroslav Flegr has reported subtle personality trends.

In men:
- Less likely to follow social rules
- More suspicious
- More prone to jealousy

In women:
- More warmhearted
- More easygoing
- Less suspicious
- Less prone to jealousy

Schizophrenia risks may also increase with infection, says Robert Yolken of Johns Hopkins Children's Center in Baltimore. He suspects that multiple pathogens can push a beleaguered brain toward the disorder. Like the virus herpes simplex type 1, brain invader *T. gondii* fits the profile of a potential contributor.

T. gondii spends years among brain cells. And Yolken says, "it's not totally latent—it's doing things." The cysts may boost dopamine in unnatural ways; the haloperidol used in Webster's rat experiment, after all, is prescribed in people for schizophrenia. Or, Yolken says, inflammation caused by cysts in the brain could disrupt behavior.

Whatever the mechanism, the link between parasite infection and schizophrenia looks moderately strong based on 38 studies, Yolken and his colleagues concluded last May in *Schizophrenia Bulletin*.

One of the earliest studies reviewed by Yolken, as well as E. Fuller Torrey of the Stanley Medical Research Institute in Chevy Chase, Md., and another colleague, dates from 1956. That era's swell of interest in pathogens and mental illness later waned as researchers looked instead to human genetics for the main cause of schizophrenia. But now that recent studies have turned up only weak links between particular genes and schizophrenia, Yolken says interest in nongenetic risks is rising again. Human genes do matter, he says, but there must be other menaces at work.

T. gondii infection is also in the parade of menaces linked to brain cancer — though feline companionship, not the infection itself, receives most of the attention.

Rates of *T. gondii* infection tracked with higher overall rates of brain cancer across 37 countries, Thomas and colleagues reported last February in *Biology Letters*. Looking just within France, a similar pattern shows up, Vittecoq, Thomas and their team reported the next month in *Infection, Genetics and Evolution*. Both papers were intended to encourage a deeper look at the question of parasites and disease, the researchers say.

Neither paper blamed cats. But together, the publications raised concern among cat owners. Though infectious oocysts can't push through unbroken human skin, parasitologists advise people to wear gloves and wash their hands thoroughly when cleaning litter boxes.

The wave of fur-related anxiety prompted Cancer Research UK's blog to emphasize that there is no evidence that the presence of cats causes brain cancer. An August 2012 comment in *Biology Letters* looked at data from 626,454 women in the United Kingdom, average age 64, to see whether cat ownership — *Toxo* infection aside — matched brain cancer risk.

It didn't, Vicky Benson and her colleagues at the University of Oxford concluded. Eighteen percent of the women in the study owned at least one cat, but there was no sign that the cats by themselves brought an extra risk for brain cancer.

The study apparently touched a nerve; headlines rejoiced: "Cats not linked to brain cancer after all" and "Good News: Cats aren't really polluting your brain with poop parasites." What didn't get as much attention was a clarification from Vittecoq and her colleagues. In a response, they cited studies from some populations showing that cat ownership isn't even a reliable predictor of *T. gondii* infection. Eating undercooked meat presents a bigger threat. The point of the original studies, Vittecoq emphasizes, is that, regardless of how someone gets a parasite, the infection itself might be linked to brain cancer. Now researchers need to take a more detailed look at the possible associations.

Even though her own paper helped raise the specter of brain cancer, Vittecoq seems to be at peace with her parasite. Trying to separate a human from all its microbes is not possible, she says.

Researchers have calculated that the microbial cells in a human body outnumber the *Homo sapiens* cells 10 to 1. "We have to learn to live with parasites in a healthy way," Vittecoq says. As for the sci-fi possibility that the parasite is changing her personality, she accepts the idea but doesn't find it worth worrying about. "One influence among many," she says.

What is worth worrying about doesn't get the press it should, grumbles Hunter, the parasitologist who studies *T. gondii*'s powers for evading immune systems. Alien mind control and crazy cat ladies make it into far more headlines than plain old public health concerns. Pregnant women get warned away from unwashed lettuce and messy litter boxes not because of the potential for personality changes but because an infected mom occasionally passes the infection to the fetus, with uncommon but possibly devastating consequences.

Even less widely discussed, *T. gondii* ranks fourth among causes of hospitalization from foodborne illness and second among causes of food poisoning deaths in the United States, according to the Centers for Disease Control and Prevention.

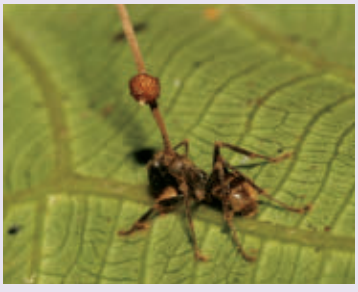
Forget about mind control. The big message may be take care when cooking and when cleaning up after cats, Hunter says. "The best microbiological health tip ever: Wash your hands." ■

Explore more

- Theme issue on neuroparasitology including the study of *T. gondii*: *Journal of Experimental Biology*. January 1, 2013.

Parasite parade

Plenty of parasites may manipulate a host to their own benefit. In these cases, the grotesque outcome can make *T. gondii*'s subtle tricks seem mild.



Ophiocordyceps unilateralis
This fungus turns infected ants into traveling zombies that take hold of plants in just the right neighborhood for fungal spores to prosper. After the breakdown of an ant's internal tissues, fruiting bodies emerge from its head.

Ampulex compressa
The jewel wasp precisely stings a roach to take over control of the roach's walking. Then the wasp leads its zombie to the wasp burrow. There, the roach is kept alive long enough for baby wasps to feed and grow.

Paragordius tricuspidatus
This worm grows within a cricket host. When it reaches the right size and is ready to emerge, it induces the cricket to leap into water. The worm slithers out to find a mate; the cricket usually dies.

FROM TOP: MAJ-BRITT PONTOPPIDAN *ET AL/PLOS ONE* 2009; COURTESY OF FREDERIC LIBERSAT AND RAM GAL; PASCAL GOETGHELUCK/SCIENCE SOURCE

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The Universe Within: From Quantum to Cosmos

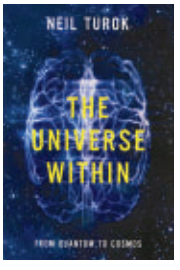
Neil Turok

There's no shortage of smart, literate physicists — think Lisa Randall, Steven Weinberg or Brian Greene — whose popular writings bring the universe into sharp focus. But Neil Turok, director of Canada's Perimeter Institute for Theoretical Physics, also brings humanity into the mix of cosmic questions.

On some levels, *The Universe Within* is a typical whirlwind tour of physics' richest discoveries, from the unification of electricity and magnetism to the discovery of the expanding universe. Turok sails through the greatest hits while tucking in nuggets such as what it's like to work with Stephen Hawking.

On other levels, the book is a call for radical societal change. Turok frames his arguments around the power of the human mind, and his new twist is a consideration of the future. Superfast quantum computing, he predicts, will soon become reality and will shape how we think, reason and discover. Surrounded by quantum computers that respond to every inquiry in a flash, the human mind will become the universe within.

Which all sounds wonderfully futuristic — but how will this come about? By tapping underexploited scientific talent, Turok argues. An African whose parents were jailed for protesting apartheid, he is a fierce advocate for education.



In 2003 Turok helped found the African Institute for Mathematical Sciences, a training ground for the continent's brightest minds. And last fall he preached his main arguments in a series of lectures across Canada (check them out on iTunes or at bit.ly/SNmassey).

Only when all minds have the chance to learn about and explore the cosmos will Turok's richly imagined future surpass the insights of past discoveries. *— Alexandra Witze*

Anansi, 2012, 280 p., $15.95

Naked Statistics

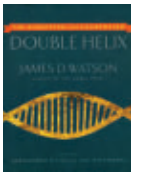
Charles Wheelan

Despite a reputation for being worse than damned lies, statistics conquered its enemies during the 20th century and now reigns over science. What happens in a scientific experiment is considered unworthy of serious consideration (that is, you can't get it published) unless formulas determine that the result is "statistically significant."

Those formulas involve all sorts of obscure concepts such as the central limit theorem, correlation coefficients, standard deviation and regression analyses — all involving mathematical wizardry that would be relegated to books in the restricted section of the Hogwarts library. But Wheelan, a Dartmouth economist, has provided a volume offering safe reading for all ages. With humor and an engaging conversational style, he walks the reader through the basics of statistical concepts and their applications, using real-world examples to illustrate how statistics work and why they matter.

All in all, it's an excellent book. But with subtle weaknesses. Wheelan ignores Bayesian statistics, which is often the more appropriate approach for dealing with many of the issues he discusses. And in a chapter toward the end (called a "warning label" about common statistical mistakes), he discloses that the methods he has been presenting often don't work. "A shocking amount of expert research turns out to be wrong," he writes. Yet throughout most of the book he presents standard statistics as the way to get right answers. In many cases, however, statistics stripped of its mysteries turns out to be an emperor with no clothes. *— Tom Siegfried*

W.W. Norton & Co., 2013, 282 p., $26.95



The Annotated and Illustrated Double Helix

James Watson; Alexander Gann and Jan Witkowski, eds.

Watson's 1968 memoir of the discovery of DNA's structure gets a stylish update, with an extra chapter and added photographs and documents. *Simon & Schuster, 2012, 345 p., $30*

Longleaf, Far as the Eye Can See

Bill Finch, Beth M. Young, Rhett Johnson and John C. Hall

A series of photographs enriches this tribute to disappearing longleaf pine forests, which once covered over 90 million acres of North America. *Univ. of North Carolina, 2012, 176 p., $35*

Spectrums

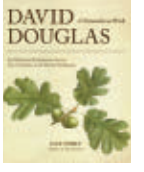
David Blatner

Explore the wonders of six kinds of spectra — numbers, light, sound, size, heat and time — that define the universe. *Walker & Co., 2012, 183 p., $25*

King of Poisons

John Parascandola

This history of arsenic shows how the compound has been used, from candy to nefarious plots. *Potomac Books, 2012, 197 p., $27.50*



David Douglas: A Naturalist at Work

Jack Nisbet

Discover the natural history of the Pacific Northwest through the tale of a naturalist who explored the region 200 years ago. *Sasquatch Books, 2012, 191 p., $27.95*

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No one is clear about how glass forms, but Patrick Charbonneau is looking at the problem in a new way.

Through a glass, less darkly

After finishing his Ph.D. on glass formation, chemical physicist Patrick Charbonneau thought he'd never study the material again. But something kept nagging him: In some experiments, materials would unexpectedly morph into glass, solid as a rock but molecularly disordered like a liquid. The results didn't match with glass-formation theory, but they were easy to dismiss as a fluke. "If I want to have a career," Charbonneau remembers thinking, "there's no way I should work on this problem. It's ridiculous."

Other researchers had found mismatches between the theory of how glasses form and actual glassmaking (real or simulated on a computer). But most blamed the discrepancies on experimental conditions, impurities, inherent material properties — such as the shapes of molecules — or other factors. Charbonneau wasn't satisfied with those explanations, though, and started moonlighting to learn more. He found a collaborator in his cousin's husband, a mathematician who "owed him," Charbonneau jokes, for the matchmaking with his cousin. The friends settled on repaying the debt through solving math problems together: "We meet at family gatherings, and when the aunts and uncles find us to be a little too boring, we sit down in the corner and start doing math."

After months of frustration, Charbonneau, now at Duke University, realized that the pair didn't really understand what was happening in glass mathematically. Researching the literature, he found no experiments that tested a decades-old theory that described glass formation in three-dimensional space but not for higher dimensions. Then came a moment of clarity. "People have been looking at the consequences of that theory without having carefully checked the assumptions," he concluded.

Finally putting theory to the test, Charbonneau and his team simulated glass formation in four-dimensional space and higher, eventually proving that a crucial assumption of that early glass-formation theory was wrong: The molecular structure within glass is much more disorderly than had been thought. The results and Charbonneau's methods — simulating each assumption in the lab before theorizing further — are spreading across the glass-research community like a tiny crack across a windshield. That's prompting some glass researchers to think about repairing their glass-formation theories, others to consider replacing them and still others to ignore the crack, perhaps hoping it won't spread further. — *Robert Frederick*

Many forms of glass
The traditional recipe for making glass, such as these Roman urns (top), is thousands of years old: silica (sand), sodium carbonate (soda) and calcium oxide (lime).Today, glass is also made from thermoplastic polymers that form polycarbonates, varieties of which are made into bulletproof glass (bottom), eyeglass lenses and DVDs.

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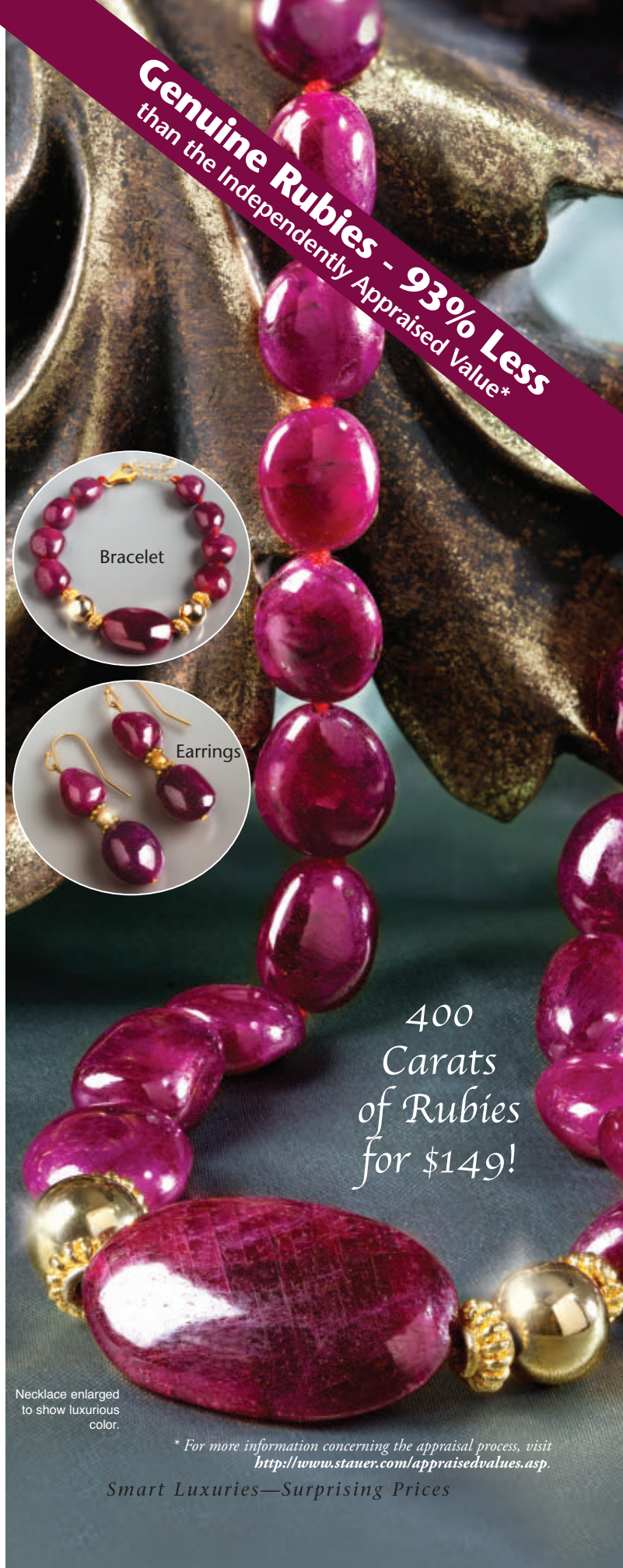

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