SN
SCIENCE NEWS MAGAZINE
SOCIETY FOR SCIENCE & THE PUBLIC
MARCH 21, 2015

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Sam Ting's quest to unmask dark matter

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ScienceNews


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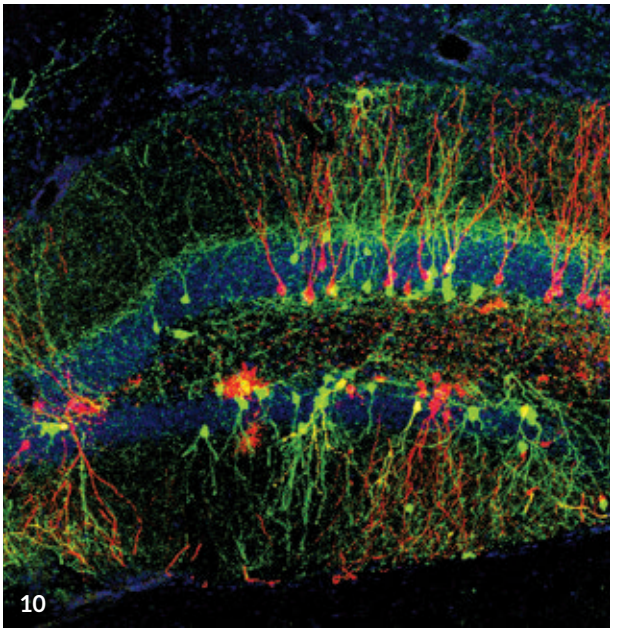
Features

News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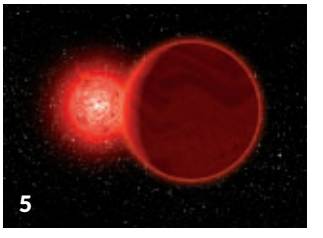
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Departments

COVER Sam Ting, who won a Nobel Prize at age 40, continues to explore big-picture questions, most recently analyzing cosmic rays to investigate dark matter and anti-matter. *Chris Thornley*

CLOCKWISE FROM TOP: EYE OF SCIENCE/SCIENCE SOURCE; MICHAEL OSADCIW/UNIV. OF ROCHESTER; M. BERGAMI *ET AL*/*NEURON* 2015

In era of collaboration, individual initiative can still pay off

Even when we don't say it explicitly, much of the science reported in this magazine is the result of collaboration and teamwork, both small (such as the duo predicting a shrinking range for lemurs described on Page 5) and large (such as the expansive study of the human epigenome reported on Page 6, which involved more than 60 teams with upwards of 150 researchers taking part in the analysis alone).

The Alpha Magnetic Spectrometer is no exception. Hundreds of people helped to fund, design, build and transport the cosmic ray detector to its perch aboard the International Space Station. But, as physics writer Andrew Grant describes on Page 22, the AMS is truly the brainchild of Nobel laureate Samuel Ting, the singular force behind making the detector a reality.

The AMS is a long shot. It senses charged cosmic ray particles that may help answer two of the biggest questions in physics: What is dark matter? What happened to all of the antimatter that should have existed in the early universe? If the AMS gamble pays off, it will provide new clues to the identity of the dark matter, which other cosmic ray experiments have failed to reveal. Studying a surprising surplus of positrons in space, the AMS could deliver data about the mass of a dark matter particle, essential information for explaining its nature. That would make the effort well worth it. It's less likely that the AMS will catch a primordial antimatter particle. But if it does, scientists might have a better chance of understanding the imbalance of matter and antimatter in the universe we see today. That, too, would be a big win for science.

What's interesting about Ting and the AMS is the risky nature of the enterprise — which, along with its price tag, has attracted its fair share of critics. It truly is an experiment: putting a bucket out in space and seeing what falls in. It may help unravel nature's secrets or it may not. Yet Ting himself never wavers. He wants to ask the question, collect the data, do the experiment, see what's out there. And whatever the result, it's hard to argue with that urge, which is at the heart of the scientific process.

— Eva Emerson, Editor in Chief

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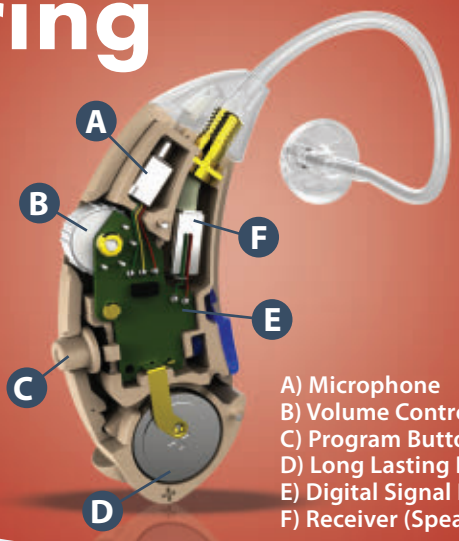

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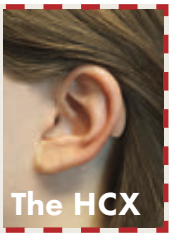
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Excerpt from the March 20, 1965, issue of *Science News Letter*

50 YEARS AGO

Animal proteins provide a study of evolution

Protein molecules in the blood of monkeys and other near relatives of man could be used to shed light on molecular evolution and evolution of apes and man.... By studying the structure and changes in protein molecules of various living animals ... scientists can understand the way the molecule evolved, reported Dr. John Buettner-Janusch of Yale University ... and Dr. Robert L. Hill of Duke University.

UPDATE: Molecular evolution techniques now focus on DNA. Four of *SN*'s Top 25 stories of 2014 (*SN: 12/27/14, p. 14*) involved the methods, revealing the genetic histories of humans, insects, birds and domesticated animals. Odder was the fate of one of the scientists who proposed the methods: Buettner-Janusch, an influential physical anthropologist, was convicted in 1980 of making LSD and other drugs in his laboratory and served three years before receiving parole. In 1987, he pleaded guilty to having sent poisoned Valentine's Day chocolates to the judge in the drug case. The scientist died in prison in 1992.

IT'S ALIVE

The running of the quolls

Northern quolls are cute until you have to handle one and cope with its teeth.

Male Northern quolls live fast and die young in a romantic frenzy of long-distance travel. And that's only part of the reason why animal athletics specialist Robbie Wilson of the University of Queensland in Australia chases quolls with a plastic block.

Boldly polka-dotted marsupials a bit bigger than a squirrel, Northern quolls (*Dasyurus hallucatus*) are among the very few mammals that practice the lifestyle called semelparity, living for only a single, albeit intense, breeding season. They're the furry, four-legged equivalent of salmon or petunias. Among Northern quolls, males are the one-season wonders. Females live for two or three.

Male quolls grow up in about 11 months. "Then obviously something switches in their brains, and they go, 'Oh my gosh, I need to find as many females as possible and mate with them,'" Wilson says. "They run extraordinarily long distances to find the females. They pretty much stop thinking about finding food."

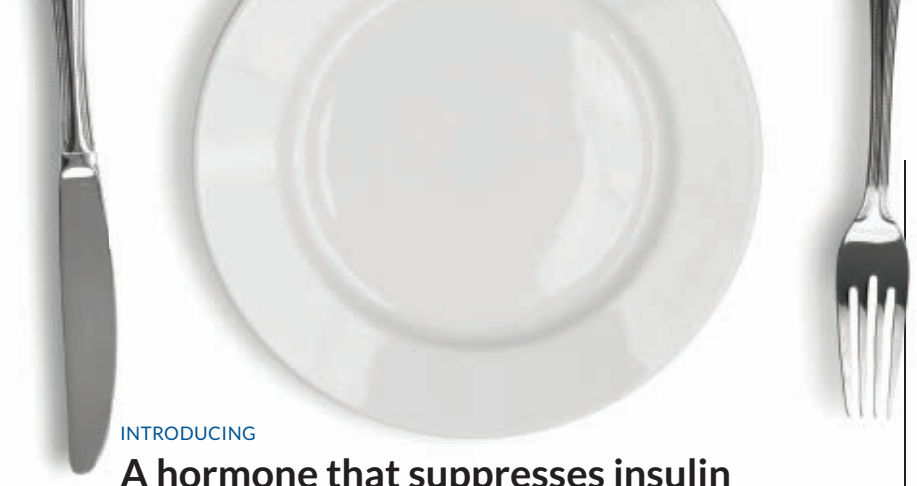
All that running is hard on the fellas. "You get these beautiful big males that two weeks later have lost their hair, lost their muscle mass," he says. "They can hardly walk. They've got puffy sores all over them, and they keel over and die."

Just how far and fast these binge marathoners travel should become clearer as Wilson and his colleagues collect data from quoll-tracking instruments. The researchers can already say how maneuverable the species is, which could be an overlooked but important feature of how the imperiled animals cope, or don't, with introduced predators such as cats and foxes.

Quolls can race around sharp corners, averaging 1.5 meters per second in a 135-degree turn, Wilson and his colleagues report in the Feb. 1 *Journal of Experimental Biology*. That's on a quoll speedway (with protective rubber in the potential marsupial crash zone) custom built with an adjustable bend. The track sits on the remote Groote Eylandt, an island where Northern quolls are abundant. Scientists chased quolls through the track with a soft plastic block on a pole. "The animals were much faster than we were," Wilson says.

Wilson takes pains to explain the big issues behind his work to bystanders at the track. But despite the broader importance, even he acknowledges, "When it's all set up, it looks completely ridiculous." — *Susan Milius*

SKYE CAMERON



INTRODUCING

A hormone that suppresses insulin

A long-sought hormone that plays a role in regulating glucose has been captured by researchers studying fruit flies. The hormone, limostatin, lowers production of insulin and prevents its release from cells.

Insulin instructs cells to burn the sugar glucose. Scientists have theorized for decades that there must be a hormone that stops insulin from being made or released, so that people and animals don't burn through all their glucose and starve to death after skipping a few meals.

To find it, Ronald Alfa of Stanford University and colleagues sent fruit flies to their cages without food for a day. Lab tests unveiled a hormone that is made when flies are fasting. The hormone reins in insulin, the team reports in the Feb. 3 *Cell Metabolism*. The researchers named the new hormone after Limos, the Greek goddess of starvation.

A similar hormone called Neuromedin U may play the same role in humans. Flies that lack limostatin get fatter than usual. People who have mutations in the Neuromedin U gene are also obese and have other metabolic problems. — *Tina Hesman Saey*

SCIENCE STATS

Lemurs' lamentable land losses

All 103 species of lemur live in Madagascar, and scientists recognize many threats to the primates: They are under pressure from invasive species, logging, poaching and the island's increasing human population. Plus, the climate is changing.

Jason Brown and Anne Yoder of Duke University analyzed how expected changes in temperature and rainfall across the island may affect the ranges of 57 species of lemur over the next 65 years. Even without the other pressures, many species are at risk from climate change, the authors conclude.

60
percent
Fraction of lemur species that will experience large reductions in their ranges by 2080

6
lemur species
Number of species with ranges expected to decrease by at least 99 percent by 2080

SOURCE: J.L. BROWN AND A.D. YODER/*ECOLOGY AND EVOLUTION* 2015

THE -EST

Closest star approach to the sun

Stars generally don't rub shoulders with one another. Scholz's star, however, is an exception. Roughly 70,000 years ago, the star — or, more precisely, the pair of stars orbiting each other — came within about 0.8 light-years of the sun. Our next-door neighbor star, Proxima Centauri, is more than five times that distance. The star flyby is the closest known.

Astronomer Eric Mamajek of the University of Rochester in New York and colleagues worked out the duo's journey after measuring their current speed and direction. When the stars buzzed the solar system, they probably slipped inside the Oort cloud, a shell of trillions of comets hypothesized to envelop the solar system, the researchers report in the Feb. 10 *Astrophysical Journal Letters*.

Even during their closest approach, the stars (illustrated, with the sun in the distance at left) would have been invisible to the naked eye. One of the stars, however, occasionally flares. It's possible, the researchers speculate, that humans at the time — some of whom were wandering out of Africa — could have seen Scholz's star flicker into view for a few minutes or hours. — *Christopher Crockett*

FROM TOP: ANDREY_KUZMIN/ISTOCKPHOTO; MICHAEL OSADCIW/UNIV. OF ROCHESTER

GENES & CELLS

Chemical marks on DNA cataloged

Clues to Alzheimer's, cancer emerge from epigenetic data

BY TINA HESMAN SAEY

A series of fine-tuned maps of DNA packaging in human cells reveal dynamic new views of how the genome's instructions are carried out to build a person. The work also offers surprising insights into what goes wrong in diseases such as Alzheimer's and cancer.

The maps and discoveries made after examining them appear in more than 20 scientific papers published February 18 in *Nature* and other journals by a large consortium of researchers involved with the Roadmap Epigenomics Project.

Researchers in the project cataloged chemical modifications of DNA and its associated proteins in 111 types of human cells. Those chemical modifications are called epigenetic marks. They include the attachment of molecules, such as methyl groups or acetyl groups, to one of the histone proteins around which DNA winds in cells. Researchers mapped five different types of modifications to histone proteins in each cell type and also noted where methyl groups had been attached to the DNA base cytosine. Such modifications don't alter genes themselves, but affect how and when genes are active.

Over a decade ago, scientists compiled the full set of genetic instructions in people, the human genome sequence. Nearly every cell in the body contains an identical copy of this genetic instruction book, essentially a list of parts needed to build a person. The new maps supply directions for snapping those parts together.

Flipping through the maps of each type of cell makes the genome come alive, says Eric Lander, a human geneticist at the Broad Institute of MIT and Harvard. "If the Human Genome Project was 'Human Genome: The Book,' then this is 'Human Genome: The Movie,'" says Lander, who was not involved in the new work.

Teams of researchers used various techniques to map the epigenetic marks and find active genes — ones from which DNA instructions are copied into RNA and then proteins — and to reveal which pieces of DNA are important for regulating this gene activity. Inactive areas of the genome were charted as well.

The scientists also pinpointed cell types in which genetic variants associated with specific traits, such as cholesterol levels or blood pressure, were active. For instance, parts of the genome containing genetic variants that influence cholesterol levels were active in the liver. That result was expected because the liver produces cholesterol.

One surprise, however, was that genes containing variants associated with Alzheimer's disease were more active in immune cells rather than in nerve cells in the brain. That result was confirmed in studies of mice. Researchers led by computational biologist Manolis Kellis and neuroscientist Li-Huei Tsai, both at MIT and the Broad Institute, mapped active and inactive genome regions in mice prone to Alzheimer's. Many of the regulatory patterns found in mouse brains matched the pattern in human brains.

Previous research had suggested that immune cells in the brain called microglia play a role in Alzheimer's (*SN: 1/10/15, p. 12; SN: 11/30/13, p. 22*), but most researchers thought that neurons were the source of the disease. The new work suggests that genetic factors leading to Alzheimer's are not active in neurons at all, but manipulate microglia instead. "It doesn't just say, 'microglia are important,' it's saying 'microglia are it,'" Kellis says.

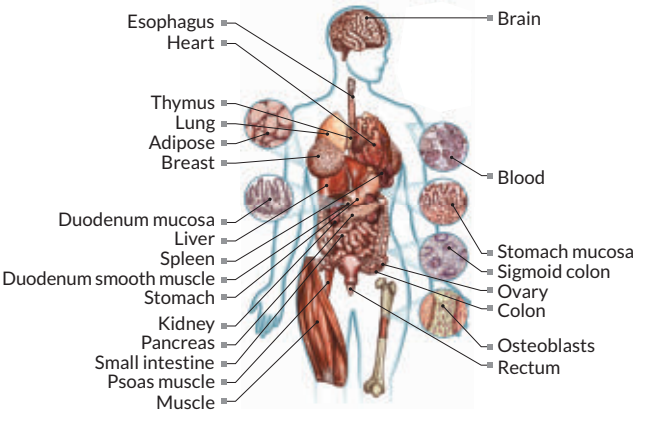
The study also revealed that PU.1, a protein that turns on genes in immune cells, goes awry in Alzheimer's. That protein may be a good target for new drugs against Alzheimer's, Kellis says.

Another study examined cancer cells. DNA-damaging mutations associated with cancer are more likely to occur in tightly packaged, inactive regions of the genome, John Stamatoyannopoulos of the University of Washington in Seattle and colleagues report. Mutations might build up in inactive regions because DNA repair machinery can't get in to fix the damage, he speculates.

Comparing mutation patterns in cancer cells with epigenetic maps can help determine what type of cell a cancer arose from. For instance, the skin cancer melanoma arises from pigment-producing cells called melanocytes. The mutations in melanoma cells occurred in parts of the melanocyte genome that are normally turned off. That pattern is different from the epigenetic maps of other types of skin cells, indicating that the cancer sprang from a melanocyte gone rogue.

Doctors may be able to match mutation patterns of a patient's cancer cells to epigenetic maps of various cell types to figure out the identity of the cell that originally turned cancerous. Such a diagnosis would be helpful for people whose cancer has spread throughout the body and its origin isn't known. ■

Body map
Researchers mapped chemical tags on DNA in 111 different tissues and cells (including those pictured here). Those chemical tags, or epigenetic marks, supply the directions needed to build a person from a parts list contained in DNA.



ROADMAP EPIGENOMICS CONSORTIUM

The past according to Planck: Cosmologists got a lot right

New analysis confirms basic ideas about universe's properties, but some unsolved puzzles linger

BY ANDREW GRANT

A new analysis of the universe's first light has cosmologists simultaneously patting themselves on the back and scratching on their chalkboards. The results, obtained from the Planck satellite and posted online in February in a set of papers at arXiv.org, largely support the theoretical framework that cosmologists employ to describe the universe. But there are also some puzzling findings, hinted at in previous research, that could signal undiscovered physical phenomena.

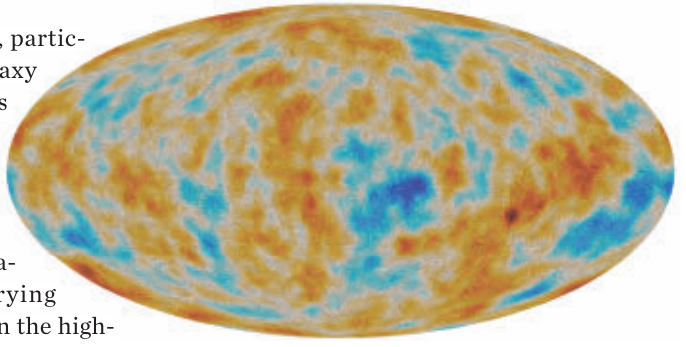
"The old model of the universe is doing remarkably well," says Shaun Hotchkiss, a cosmologist at the University of Sussex in Brighton, England. "But everything that was anomalous in the past is still anomalous." The Planck results also have a lot to say about inflation, the theorized period just after the Big Bang in which the universe swelled rapidly.

Cosmologists can describe the universe reasonably well with a model based on six quantities, including the universe's expansion rate and the density of ordinary matter. The Planck mission has chimed in with four years of measurements of the cosmic microwave background, or CMB, the universe's first light. It was emitted about 380,000 years after the Big Bang.

> "The old model of the universe is doing remarkably well."
>
> **SHAUN HOTCHKISS**

The latest data support the standard cosmological model and pin down five of the six numbers with 1 percent precision, says Planck project scientist Charles Lawrence. Those numbers describe a universe that started with a brief episode of inflation and since has been guided by a combination of regular matter, an invisible substance called dark matter, and dark energy, which causes space to stretch apart at an ever-increasing rate.

Yet the results include discrepancies that also showed up in Planck's 2013 data release and other microwave background observations, particularly the number of galaxy clusters. Planck detects subtle temperature variations in the CMB, which reflect quantum fluctuations in the early universe that got amplified by inflation into regions of varying density. Over time, mass in the high-density regions should have clumped together to form intricate galaxy clusters. But Planck data suggest there should be more clusters than scientists observe. The tension warrants further study but not any new theories just yet, Hotchkiss says.



Patterns in the cosmic microwave background radiation (coloring shows temperature differences) provide clues to how matter was distributed when the cosmos was young, allowing scientists to infer properties of the universe.

PLANCK COLLABORATION/ESA

Physicists are also pondering the expansion rate of the universe, known as the Hubble constant. Planck data indicate that objects located a megaparsec (about 3.3 million light-years) away from each other move apart at roughly 68 kilometers per second. That's not much of a change from 2013, but it is about 6 km/s slower than estimates obtained by measuring the distance and velocities of supernovas and stars called Cepheid variables, which predictably fluctuate in brightness (*SN: 4/5/14, p. 18*). An improved Cepheid survey expected to be released later this year will determine whether a discrepancy remains, says Daniel Scolnic from the Kavli Institute for Cosmological Physics at the University of Chicago.

Even if these issues are resolved, the standard cosmological model won't be in the clear. Robert Kirshner, a cosmologist at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass., says the model relies on several unproven assumptions, including that the repulsive strength of dark energy per unit volume has remained constant. Kirshner and other scientists are performing surveys to track dark energy's influence over time.

The model also fails to explain why and how inflation occurred. Planck's data refuted last year's claim by the BICEP2 team of detecting primordial gravitational waves, which would have helped physicists identify a mechanism and energy scale for that crucial instant in cosmic history (*SN: 2/21/15, p. 13*). Without a gravitational wave detection, "we do not have a definitive idea on how to connect our ideas about fundamental physics with inflation," says David Spergel, an astrophysicist at Princeton University.

The Planck analysis also used BICEP2's data to place more stringent limits on the value of r, a ratio that compares gravitational wave and matter density deviations in the CMB. The finding that r is probably less than 0.09 disfavors simple versions of inflation, such as quadratic and natural inflation, used in cosmology textbooks, Lawrence says. Those versions were already getting squeezed in 2013 when Planck suggested r was less than 0.11.

Theorists will hone their ideas to jibe with the latest data. Meanwhile, BICEP2 and a cadre of new experiments will continue probing the skies over the South Pole for the faint signals of gravitational waves. ■

LIFE & EVOLUTION

Bluebird moms fuel interspecies war

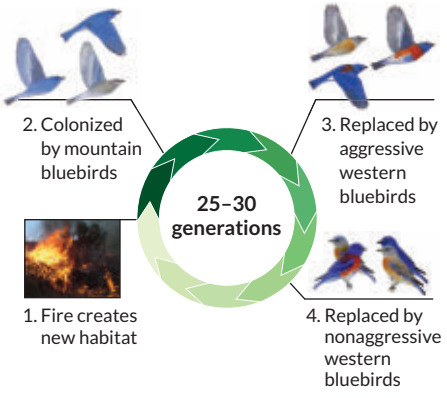
Extra hormones delivered to sons promote aggressive invasions

BY SUSAN MILIUS

Bluebird wars begin with the vexation of moms in their nests.

Experiments show that female western bluebirds (*Sialia mexicana*) harassed by other species competing for nesting cavities tend to lay eggs with abundant testosterone. Sons from these eggs grow up to be especially aggressive, says evolutionary ecologist Renée Duckworth of the University of Arizona in Tucson.

Taking over Bluebird communities change after a fire creates a perfect habitat for warring species.



Those sons are also likely to leave their parents' territories far behind in seeking breeding space of their own, Duckworth and her colleagues report in the Feb. 20 *Science*. When these restless, aggressive males discover new swaths of burned-over land, a paradise for bluebirds, they often drive away the milder-mannered mountain bluebirds (*S. currucoides*) that settled there first. The invaders can take over in just five or six generations.

In the new habitat, western bluebird moms don't juice up their eggs with extra hormones. In time, new generations of less aggressive, stay-nearby males replace the tough guys — until fights over nesting sites stress out the moms again.

Scientists have already determined that mothers have profound influences over their offspring, says Ben Dantzer of the University of Michigan. "But we don't know very much about their evolutionary and ecological consequences, especially in wild animals," he says. And tracing any small, local process, mother-related or not, to its large-scale ecological consequences is an achievement in itself.

Duckworth has followed large-scale wars between western and mountain bluebirds in the northwestern United States for 15 years. Both species thrive where forest fires leave plenty of cavity-riddled damaged tree trunks for nesting and create new open space with grasshoppers and caterpillars to eat.

Earlier work hinted that the hormones western bluebird moms contribute to eggs might play a role in the waves of aggressive invaders. So Duckworth set up extra nest boxes to take the pressure of competition off some females. That competition doesn't come from bluebird species, Duckworth says. Blue-on-blue fights over nest cavities get settled before eggs start forming in the females' bodies. Instead, the researchers saw other cavity-nesting species, particularly tree swallows, harass the western bluebirds during the egg-forming phase.

Tests showed that western bluebird mothers facing more competition dosed their eggs with more testosterone and related compounds. In these clutches, the mothers produced males earlier in the egg-laying order, but all offspring were hormonally nudged toward aggression. ■

GENES & CELLS

For penguins, it's a matter of no taste

Birds lack genes to savor some flavors of fish they consume

BY TINA HESMAN SAEY

Despite their dapper appearance, penguins have remarkably little taste.

Penguins can't taste bitter, sweet or the savory taste known as umami, researchers report in the Feb. 16 *Current Biology*. The jury is still out on whether the birds can taste salty and sour.

Taste ability depends on proteins called receptors in the outer membrane of taste bud cells. Once receptors detect a molecule responsible for a particular taste, they send a message to the brain about what's tripping across the tongue.

Researchers Huabin Zhao of Wuhan University in China and Jianwen Li at BGI-Shenzhen in China combed through the genomes of Adélie penguins and emperor penguins and found genes that are known to create salty and sour taste receptor proteins, but none for the other tastes. Evolutionary geneticist Jianzhi Zhang of the University of Michigan then helped the team search for umami, bitter and sweet receptors in penguins.

Zhang was skeptical that penguins would lack umami receptors. But after his own analysis, he concluded they "are truly lost," he says. Adélie and emperor penguins were also missing receptors for sweet and bitter. Chinstrap, rockhopper and king penguins also lack functional umami, bitter and sweet receptor genes, suggesting that the genes were missing in the common ancestor of all penguins.

Researchers knew that birds lack sweet receptors. But bitter's desertion is harder to swallow. Many poisons made by plants are bitter, thereby serving as a warning, says neurobiologist Peihua Jiang of the Monell Chemical Senses Center in Philadelphia. Since penguins eat mostly fish, they may not need bitter receptors for detecting poisonous plant compounds.

Penguins aren't the only animals that lack the ability to taste bitter, sweet and umami, Jiang adds. Previous studies have shown that dolphins, sea lions and whales are all missing those taste sensations.

Zhang notes that all three tastes require a protein called Trpm5, which is impaired by cold temperatures. Swimming in freezing water may have killed penguins' taste anyway, making it no big deal for the genes to be lost. ■

R.A. DUCKWORTH *ET AL*/*SCIENCE* 2015

Brain at rest offers clues to Parkinson's, Alzheimer's

PET scans of patients pick up clear signals indicating deterioration of neural network

BY TINA HESMAN SAEY

An important brain network breaks down differently in Parkinson's and Alzheimer's diseases, a new study finds.

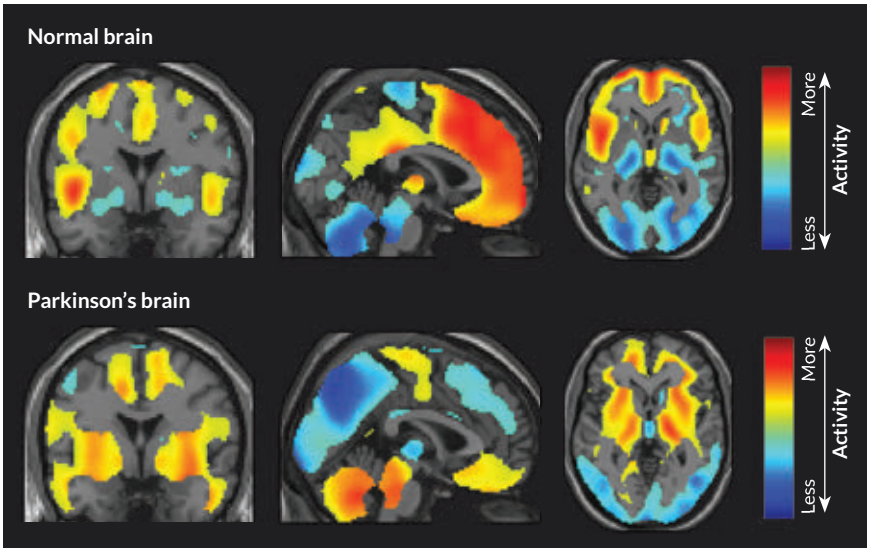
Measurements of how much glucose brain cells consume reveal that one important resting network, called the default mode network, rapidly and continually loses activity in people with Alzheimer's disease. In contrast, the network remains largely intact during the early stages of Parkinson's disease but not necessarily in charge, researchers report in the Feb. 24 *Proceedings of the National Academy of Sciences*.

The default mode network is a set of brain regions that are active when people are sitting quietly and thinking of nothing in particular. Scientists debate the network's role, but some evidence has indicated that it deteriorates in a wide variety of brain disorders and diseases (*SN: 7/18/09, p. 16*).

Researchers usually study the default mode network using brain scans known as functional magnetic resonance imaging, or fMRI. That technique measures blood flow, which is an indirect gauge of brain cell activity. David Eidelberg, a neuroscientist at the Feinstein Institute for Medical Research in Manhasset, N.Y., and colleagues used a more direct brain imaging technique, known as a PET scan, to measure how much glucose brain cells use. The more active brain cells are, the more glucose they burn.

Initial tests in healthy people showed that PET scans can detect the default mode network, just as fMRI scans do. In fact, the network signals were stronger in PET scans than in fMRIs, Eidelberg says.

The scientists then analyzed PET scans of the brains of Parkinson's and Alzheimer's patients. Scans showed that the default mode network was no longer the dominant resting network in Parkinson's patients. "There was a new sheriff in town" in the form of an abnormal network not seen in healthy people, Eidelberg says.



PET scans reveal the regions of the brain that are active when people are not thinking about anything in particular. In healthy people, these coordinated areas are called the default mode network. In people with mild to moderate Parkinson's disease, a new, abnormal network starts to take over.

P.G. SPETSIERIS *ET AL/PNAS* 2015, ADAPTED BY S. EGTS

In the early stages of Parkinson's, this abnormal network dominated resting brain activity but otherwise didn't interfere with the default mode network. As the disease progressed and the patients developed dementia, the default mode network started to break down, the researchers found. But the network's activity could be partially restored by treating patients with levodopa, a drug that converts to dopamine in the body (*SN: 8/23/14, p. 15*).

To study Alzheimer's disease, the researchers examined PET scans from a database compiled by the Alzheimer's Disease Neuroimaging Initiative.

Alzheimer's patients also had an abnormal dominant resting network in their brains, but it was different from the network seen in those with Parkinson's disease. And unlike in Parkinson's patients, the default mode network of Alzheimer's patients had already started to decay in people with mild symptoms that couldn't yet be reliably diagnosed as Alzheimer's disease. PET scans of Alzheimer's patients taken six months, a year and two years after the initial one showed ever lower activity in the default mode network.

The differences may stem from the nature of the diseases, says Douglas Rothman, an imaging scientist at Yale University who wasn't involved in the work. In Parkinson's disease, people lose brain cells that make dopamine, which helps coordinate communication. Restoring dopamine facilitates smoother talk in the brain networks. But in Alzheimer's disease, brain cells in crucial regions of the default mode network die. "You really have a massive disruption in neuroanatomy," Rothman says. That damage probably cannot be reversed.

PET scans, which involve taking a radioactive tracer, may one day be helpful in diagnosing brain diseases at earlier stages, and in monitoring how well drugs and treatments work to slow disease progression (*SN: 3/7/15, p. 10*), Rothman says. ■

BODY & BRAIN

Age, experience rewire adult brains

Environment shapes how new, old nerve cells link up in mice

BY ASHLEY YEAGER

New experiences can rewire old brains — but the timing has to be just right.

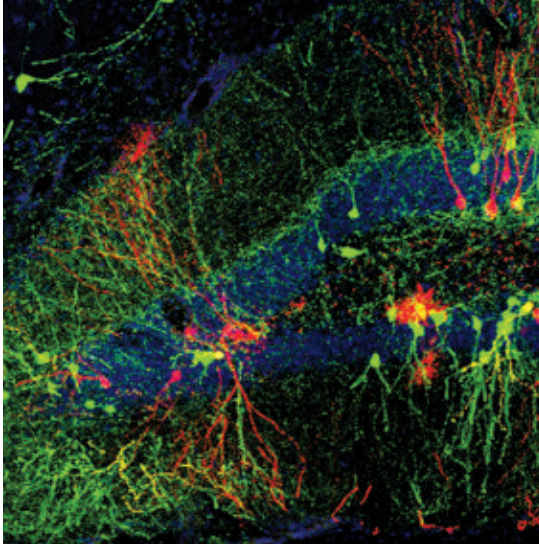
Adult mice that spend time with toys, tunnels and running wheels create many more connections between new and existing nerve cells in one part of the brain than do mice kept in toy-free cages, scientists have found. But the boost in brain rewiring happens only two to six weeks after new brain cells are born, the researchers report in the Feb. 18 *Neuron*.

"It's remarkable to think of the extent of this reorganization," says Amar Sahay, a neuroscientist at Massachusetts General Hospital and Harvard University. The work shows that the adult brain can change much more than scientists had thought, he says. The results may even help to explain why people don't all respond the same way to stress, and possibly how individual experiences shape behavior.

In the new study, Matteo Bergami, a neuroscientist at the University of Cologne in Germany, and his colleagues traced how and when new cells integrate into existing nerve circuitry in the brains of adult mice.

Adult brains make new nerve cells, or neurons, in the dentate gyrus, part of the hippocampus — a seahorse-shaped region that plays an important role in learning and memory. Experiments have shown that genetically identical mice grow more neurons in the hippocampus and develop different personalities depending on how much they explore environments with toys and tunnels (*SN: 6/29/13, p. 13*).

In addition to growing more neurons, adult mice given access to toys and tunnels develop about two to four times as many connections between those new neurons and existing neurons than do mice in regular cages, Bergami and colleagues found. Some of the connections were even long-range, linking new neurons in the dentate gyrus to other



brain regions to form circuits that may play important roles in memory and navigation. But to make the extra connections, the neurons had to be just the right age. Toys and tunnels did not increase the number of connections made by neurons younger than 2 weeks or older than 9 weeks, the team reports.

Sahay says the results could help scientists recognize similar kinds of rewiring in human brains. High-resolution imaging might detect the reorganization of some of the brain circuits revealed in the new study, he says.

Bergami says brain rewiring based on experience may play a role in anxiety and

EARTH & ENVIRONMENT

Steam carries gold, sulfur to surface

Bubble mechanism explains how metals rise up in magma

BY THOMAS SUMNER

Dense mixes of sulfur and metals such as gold can catch a lift to the top of magma reservoirs on the undersides of rising steam bubbles, new research suggests.

After heating capsules of materials found in magma, researchers discovered droplets of sulfur and metal stuck to the bottoms of floating water vapor bubbles. The mechanism may explain the large amounts of sulfur and metals expelled during volcanic eruptions and help pinpoint ore deposits, the researchers propose February 23 in *Nature Geoscience*.

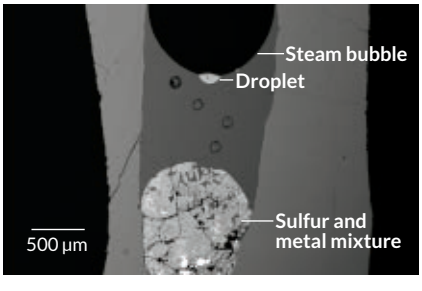
These floaters "are like little hot air balloons carrying a gondola underneath," says lead author James Mungall of the University of Toronto.

Metals in magma readily combine with sulfur. Sulfur-rich melts will typically have 10,000 times the gold concentration of the surrounding magma, for instance. This dense combination of sulfur and metal, known as a sulfide mineral, will sink and sit indefinitely at the bottom of a volcano's magma reservoir.

But volcanologists have seen blasts spew more sulfur and metal than could be carried to the surface in the erupted magma. This imbalance suggests that some unknown mechanism can raise sulfur and metal from deep inside the Earth.

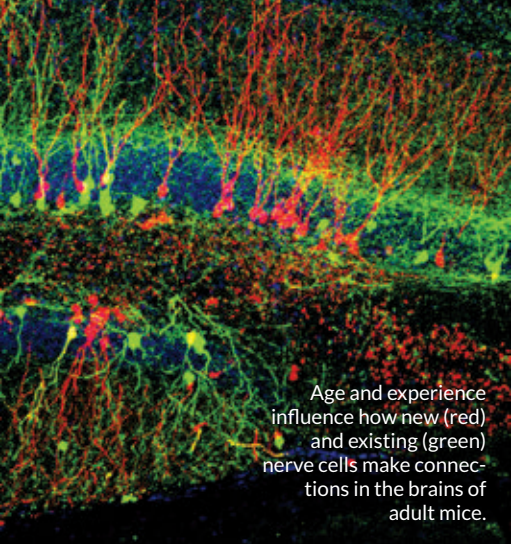
Mungall and colleagues conducted an experiment mimicking how sulfide minerals act in magma chambers. The team drilled millimeter-wide holes in crystals of heat-resistant chromite and packed the cavities with magma ingredients. The vessels then went into a furnace heated to 1,200° Celsius. After 48 hours, the team quickly cooled the creations, freezing the molten interiors in place.

When the researchers sliced open the mock magma, they discovered dense



Tiny droplets from a dense mixture of sulfur and metal can float upward in magma reservoirs on the undersides of steam bubbles, a new experiment suggests.

FROM TOP: M. BERGAMI *ET AL*/*NEURON* 2015; J.E. MUNGALL *ET AL*



Age and experience influence how new (red) and existing (green) nerve cells make connections in the brains of adult mice.

depression. Both conditions are linked to stress, which can negatively affect new neuron growth. If a person experiences something traumatic while new neurons are in that critical period of reorganizing brain connections, that rewiring could be dysfunctional, putting the individual in a constant state of anxiety. The team plans to test the idea in mice.

Brain rewiring based on experience could also play a role in humans' diverse range of personalities. "As individuals, we have quite distinct experiences in our lives," Bergami says. "The emergence of our individuality may be based on our individual set of brain connections." ■

droplets of sulfide minerals hanging from the bottoms of floating steam bubbles.

A bubble will morph its shape to minimize surface tension, with a sphere requiring the least amount of energy to hold together. When two bubbles meet, their surfaces merge to form a shared wall that reduces the total surface area that surface tension must maintain. This energy-reducing behavior may bond together the sulfide mineral droplets and steam bubbles as they float up the magma reservoir, Mungall says. Over time, the steam bubbles, which range in size from microscopic to several meters across, will absorb their hitchhiking payloads and either erupt to the surface or settle into fissures, forming metal deposits.

The explanation is "excitingly tidy," says geologist Adam Simon of the University of Michigan in Ann Arbor. ■

HUMANS & SOCIETY

DNA foretells success in intervention

At-risk kids with stress-gene variant responded best to program

BY BRUCE BOWER

A particular genetic variant can indicate whether children at risk for developing serious behavior problems are more likely to benefit from an early-intervention program, a new study shows.

Researchers are a long way, though, from being able to conduct genetic tests to identify grade-schoolers most likely to respond to such programs, cautions psychologist Dustin Albert of Duke University. When that day comes, society will have to grapple with the ethics of genetically screening at-risk kids, he predicts.

Albert and colleagues followed white youngsters who were highly disruptive and aggressive as kindergartners, and who inherited one or two copies of a gene variant involved in regulating the body's stress responses. Most of the kids who received an intensive intervention from grades one through 10 displayed dramatic behavior changes for the better as young adults. Only 21 of 114 kids in this group, or 18 percent, had abused alcohol or drugs and committed delinquent or criminal acts by age 25, Albert's team reported online January 5 in the *Journal of Policy Analysis and Management*.

A second group of kids with just as severe behavior problems and who inherited the same version of the stress gene received no intervention — and did especially poorly. As young adults, 96 of 128 of them, or 75 percent, displayed drug and delinquency problems.

Researchers also looked at at-risk children carrying other versions of the stress gene. Slightly more than half reported drug and behavior problems by age 25, whether or not they had received the 10-year intervention while in school.

Further analyses, reported by Albert's group in the February *Development and Psychopathology*, indicate that, among kids with the key gene variant, the intervention led to grade school behavior improvements. Even greater improvements occurred from adolescence to young adulthood. And participants with two copies of the modified gene benefited more from the intervention than those with one copy. "Biological sensitivity to one's environment may be related to the stress-response system," Albert says.

Children with the crucial gene variant clearly got the biggest boost from the intervention, says psychologist Michael Pluess of Queen Mary University of London. However, a fairly big range of variation in outcomes at age 25 for nonintervention kids suggests that those with and without the key gene variant ended up with comparable rates of behavior problems, Pluess holds. Albert counters that it's likelier that participants with the crucial gene variant developed more behavior problems than anyone else in the study.

His team tracked 270 white children tagged by parents and teachers as being highly disruptive upon entering kindergarten. Children attended public schools in high-crime, low-income parts of Seattle, Nashville, rural Pennsylvania and Durham, N.C. Kids were randomly assigned in the early 1990s to receive an intervention that included social skills training, parent training, academic tutoring and help with individual problems.

Once kids turned 21, researchers collected DNA from cheek swabs. The team identified 10 versions of the glucocorticoid receptor gene. This gene influences transmission of the stress hormone cortisol. Several glucocorticoid receptor gene variants have been tied to alcohol abuse and mood disorders.

Only one gene variant showed a link to favorable intervention effects, at least for white kids, Albert says. For unclear reasons, none of these gene variants signaled responsiveness to the behavioral program among 127 high-risk black youngsters. Hundreds of genes influence responses to behavior programs such as the one in the new studies, Albert suspects. ■

EARTH & ENVIRONMENT

East Coast sea levels dip to the north

Satellites resolve slope direction, end decades-long dispute

BY THOMAS SUMNER

Sea levels along North America's East Coast tilt downward as you travel north up the coastline, concludes new research reported online February 5 in *Geophysical Research Letters*.

The work resolves a dispute over the slope's direction that has lingered since the 1920s between geological surveyors and oceanographers, says study coauthor Philip Woodworth, an oceanographer at the National Oceanography Centre in Liverpool, England. The slope, which results in a roughly 30-centimeter sea level drop along the coast, will influence future predictions of sea level rise in the region, he says.

"This is quite conclusive, so it's really killed off the subject of debate," says Woodworth.

Winds, tides and ocean currents push seawater around, creating patches of high and low sea level. But even without these forces, the oceans wouldn't be flat like the water in a glass. The Earth's rotation and small-scale deviations in the planet's gravity cause ocean water to have a lumpy unperturbed state. Understanding this natural shape of Earth's oceans, called the geoid, is essential to sea level research. Whether an area has high or low sea level is relative to the geoid, rather than the seafloor or the center of the planet.

In 1927, geologist William Bowie compared tidal measurements with his own mathematical estimation of the geoid to argue that sea levels along the East Coast tilt upward toward the north. The result was opposite that predicted by oceanographers, who calculated that the Gulf Stream pools extra seawater around Florida, resulting in a downward slope heading north.

After decades of disagreement, satellites offered a precise way to track sea levels and measure the minute gravity variations that contribute to the geoid's shape. Woodworth, oceanographer Simon Higginson of the Bedford Institute of Oceanography in Dartmouth, Nova Scotia, and colleagues used GPS to precisely measure sea surface heights along the East Coast relative to the center of the Earth. The team then compared the measurements with a high-resolution geoid reconstruction created using gravity data collected by satellites. The comparison allowed the researchers to determine the actual increases or decreases in sea level relative to the geoid that are caused by forces such as currents and winds.

After comparing the geoid sea level measurements with those predicted by ocean circulation simulations, the researchers at last found agreement between the two approaches. Sea levels drop about 20 centimeters between the Florida Straits and northern Florida, eventually leveling out between North Carolina's Cape Hatteras and Canada.

"The fact that both techniques are agreeing now is very reassuring," says Woodworth. "It means we must now have a good understanding of the oceans."

This agreement may have importance beyond settling a nearly century-long disagreement, says Tal Ezer, a physical oceanographer at Old Dominion University in Norfolk, Va. Sea levels between Cape Hatteras and Boston are projected to rise faster than the global average (*SN: 7/28/12, p. 17*). The new sea level measurements will provide a better context for studying the interplay between offshore currents and coastal sea levels, he says.

"This work doesn't explain everything," Ezer says, "but it provides a good base on which to continue studying the causes of sea level rise." ■

ATOM & COSMOS

Enceladus ocean highly alkaline

Subsurface water on Saturn moon could support alien life

BY CHRISTOPHER CROCKETT

Swimming in the sea of the Saturnian moon Enceladus might be like taking a dip in household ammonia.

An ocean beneath the moon's icy crust is highly alkaline, similar to Earth's soda lakes, scientists say. The chemistry provides a peek at how the water interacts with rock in the moon's core, creating an environment in which life could arise.

Christopher Glein of the University of Toronto and colleagues used data from the Cassini mission to estimate pH. The spacecraft passes through plumes that are thought to spray water from the moon's ocean (*SN: 9/6/14, p. 15*). Using measurements of the plumes' carbon dioxide and salts, the team calculated the ocean has a pH of about 11 to 12. The findings are reported February 8 at arXiv.org.

The high pH "makes a certain amount of sense," says Francis Nimmo, a planetary scientist at the University of California, Santa Cruz. Researchers think Enceladus' core resembles a pile of rubble, with nooks and crannies where water can interact with rock. As water chemically alters the rocks, it can raise pH.

If water-rock interactions can raise pH, they may also create ingredients for life such as molecular hydrogen, Glein says. The hydrogen, in combination with organic compounds previously detected, could be used as an energy source. "It is a bit speculative," he says, but life thrives in similar environments on Earth. ■

The chemistry of plumes that erupt from a subsurface sea on Enceladus suggests that the ocean is very alkaline.

CASSINI IMAGING TEAM, JPL-CALTECH/NASA, SPACE SCIENCE INSTITUTE

LIFE & EVOLUTION

Dogs can sort people's faces

Canines pick out happy and mad expressions in photo test

BY SUSAN MILIUS

Sit. Stay. Discriminate. Dogs really may be as good as their owners claim at distinguishing emotional expressions on a human face, researchers report in the March 2 *Current Biology*.

Dogs bumping their noses against a touch screen showing just the tops or bottoms of human faces did well at picking out the happy or mad expressions, says coauthor Corsin Müller of the University of Veterinary Medicine Vienna. The dogs could pass this test when pictures showed the opposite half of faces from the half used in training. The animals still performed well when researchers mixed in parts from faces the dogs had never seen.

What dogs really understand about the emotions behind the facial expressions is not clear. But Müller calls this test the best evidence yet that animals other than humans can distinguish facial expressions of a species not their own.

Devising a way to test canine ability to detect human facial emotion has been a challenge. One test used real people weeping or just humming or talking, but it couldn't rule out the possibility that dogs used cues besides faces. Another test showed dogs photos of full faces, but left doubts over whether the pets learned a shortcut, such as looking for extra white to detect smiling happiness.

To create a new test, Müller and his colleagues used photos of happy or angry faces but blanked out either the top or the bottom. The researchers paired each happy picture with an angry one showing the same face parts, and taught some dogs to nose-bump the happy choice and some dogs to go for angry to get a treat.

Eleven dogs did well enough to graduate to the real tests. These dogs were shown the half of the face — eyes and brows, or mouth and chin — opposite to the one they had previously seen. Dogs had to pick the kind of facial expression that matched the one in their training. A simple trick like looking for teeth in a smile would not work. Dogs had to summon their experience, memories and any innate biases to choose the same expression expressed in different features.

A computer-based test finds dogs can discriminate between happy and angry human faces.

The dogs' median scores ranged between 70 and 80 percent in choosing the correct half-face.

The paper makes "a strong case" that dogs develop a kind of generalizable mental template that works for different faces to discriminate between at least two human expressions, says cognitive psychologist Kun Guo of the University of Lincoln in England.

Alexandra Horowitz, a cognitive scientist at Barnard College in New York City, agrees the test shows dogs distinguishing visual stimuli. "Whether that amounts to understanding or appreciating emotion is another question entirely," she says. ■

ANJULI BARBER/MESSERLI RESEARCH INSTITUTE

BODY & BRAIN

Stem cells help mend brain damage

Technique may someday ease radiation-related side effects

BY KATE BAGGALEY

Stem cells can help heal long-term brain damage suffered by rats blasted with radiation, researchers report in the Feb. 5 *Cell Stem Cell*. The treatment allows the brain to rebuild insulation on its nerve cells so they can start carrying messages again.

The researchers directed human stem cells to become a type of brain cell that is destroyed by radiation, a common cancer treatment, and then grafted the cells into the brains of irradiated rats. Within a few months, the rats' performance on learning and memory tests improved.

"This technique, translated to humans, could be a major step forward for the treatment of radiation-induced brain … injury," says Jonathan Glass, a neurologist at Emory University in Atlanta.

Steven Goldman, a neurologist at the University of Rochester in New York, agrees. Radiation therapy "is very effective, but the problem is patients end up with severe disability," he says. For children, the damage can be profound. These kids grow up to "have really significant detriments in their adult IQs," Goldman says.

Radiation obliterates cells that mature into oligodendrocytes, a type of cell that insulates the message-carrying part of nerve cells. Without that cover, known as the myelin sheath, nerve cells can't transmit information as well, leading to memory and other problems.

To bolster the supply of oligodendrocytes, Viviane Tabar, a neurosurgeon at Memorial Sloan Kettering Cancer Center in New York City, and her team used human stem cells to grow forerunners of the myelin-making cells. The team injected these precursor cells into different areas in the brains of 18 rats that had been given a regimen of radiation similar to what cancer patients receive.

After 10 weeks, treated rats performed better than nontreated rats in tests of learning, memory and balance.

Rats given the cells in their forebrains were better at recognizing when an object had been moved or noticing an unfamiliar object. Rats injected in the cerebellum, which is responsible for motor control, trotted on a rotating pole for a longer time without falling off. Rats needed injections in both parts of the brain to get all the benefits. ■

Watch a video of a dog choosing faces at **bit.ly/SN_dogs**

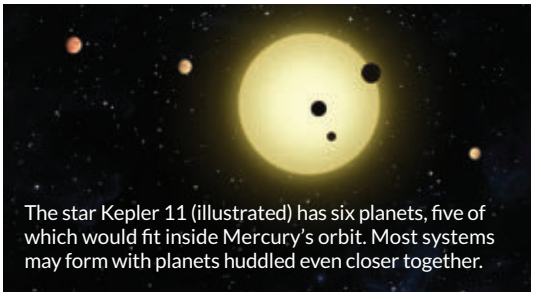
ATOM & COSMOS

Crowded systems not safe for planets

Many worlds discovered by Kepler telescope survived culling

BY CHRISTOPHER CROCKETT

Sibling rivalries among planets can turn deadly. Families of worlds huddled close to their stars might destroy one another, leaving behind just one or two survivors. These family feuds probably erupt in planetary systems that form much differently than our own, though it's possible our solar system suffered similar growing pains.



The star Kepler 11 (illustrated) has six planets, five of which would fit inside Mercury's orbit. Most systems may form with planets huddled even closer together.

Many multiplanet systems discovered by the Kepler space telescope live on the edge of stability, astrophysicist Yanqin Wu and her student Bonan Pu report online February 19 at arXiv.org. If the planets were any closer together, they would have already nudged each other off course and collided. Wu and Pu, of the University of Toronto, propose that the planets in these systems are survivors from a more diverse population. Over time, planets that formed even closer together were whittled away until just one or two worlds remained.

The Kepler telescope spent nearly four years monitoring over 150,000 stars. "One of the most important things we learned," says Anders Johansen of Lund University in Sweden, "is many systems are rich in planets." Kepler 11, for example, hosts six worlds; the orbits of five of those planets would fit inside the orbit of Mercury.

Wu and Pu ran computer simulations and found that when solar systems form, a retinue of planets bunched up close to their star might be the norm.

Our solar system, however, has a large void between the sun and Mercury. "How come we are empty where other stars in the galaxy have lots of planets?" asks Wu. Perhaps Jupiter and Saturn interfered with planet-forming dust collecting in the inner solar system. Or maybe the Kepler worlds formed farther from their stars and wandered in later.

Planetary scientist Kathryn Volk looks at it another way. "What if our solar system formed just like these Kepler systems?" she asks. She and Brett Gladman, of the University of British Columbia in Vancouver, looked at what might happen if three or so Earth-sized planets had formed inside the orbit of Venus. Not only do they eventually destroy one another, but they leave behind a Mercury-sized planet, Volk and Gladman report online February 23 at arXiv.org. That could explain why our solar system's innermost planet is so small. ■

MATTER & ENERGY

Two steps forward for teleportation

Quantum method transfers pair of particle properties

BY ANDREW GRANT

The bandwidth for quantum teleportation has doubled. A new technique transfers information about one particle so that another particle takes on two, rather than just one, of the original particle's quantum properties.

Physicists accomplished the feat by nesting one quantum teleportation apparatus inside another. "It's impressive," says physicist Wolfgang Tittel of the University of Calgary in Canada.

The achievement, reported in the Feb. 26 *Nature*, doesn't bring scientists much closer to teleporting pens, puppies or people à la *Star Trek*. But teleporting multiple properties over large distances would enhance proposed quantum communication networks that rely on encoding data in particles' quantum properties.

The researchers, led by Jian-Wei Pan and Chao-Yang Lu of the University of Science and Technology of China in Hefei, largely stuck to the tried-and-true teleportation technique. That method requires three particles (say, photons): one being teleported plus a pair that are quantum entangled. Entanglement establishes a connection between particles so that physicists can measure a property of one photon and determine what the value of that property will be when the partner photon is measured.

The experiment began with a measurement that compares a property (in this case, polarization) of the photon getting teleported with the same property of one of the entangled photons. That measurement destroys the quantum nature of both photons (and usually the photons themselves). But the information gleaned from the comparison enables physicists to manipulate the third photon so that its polarization matches that of the original photon.

Then the team added a few tricks. The researchers entangled the particle pair so that two properties — polarization plus orbital angular momentum (the "twistiness" of the photon's trajectory) — were connected. Then the physicists found a way to determine polarization while preserving the measured photons and some of their quantum properties. Whenever the polarization sensor obtained a certain measurement, one photon got fed into equipment that teleported the photon's orbital angular momentum to a new photon. One last detector compared the new photon's orbital angular momentum with that of the original entangled photon.

By completing both rounds of measurements, the physicists proved that they could manipulate the final particle so that its polarization and orbital angular momentum perfectly matched those of the original photon. ■

TIM PYLE/NASA

BODY & BRAIN

Peanut exposure prevents allergy

For many at-risk infants, early avoidance not a good strategy

BY NATHAN SEPPA

Infants getting small but regular doses of peanut butter are less likely to develop an allergy to peanuts than are similar babies who avoid peanuts altogether, a new study shows.

The finding — in infants at higher-than-usual risk of peanut allergy — calls into question the notion that peanut butter should be broadly avoided in infancy. In recent years, studies have hinted that early peanut consumption might be a better strategy to reduce susceptibility to this food allergy.

"This is the first real data to support that emerging theory," said Robert Wood, director of pediatric allergy and immunology at Johns Hopkins University. "The results of this study are dramatic. It's not a borderline effect."

Pediatric allergist Gideon Lack of King's College London and his team enrolled babies ages 4 to 11 months who were deemed at elevated risk of peanut allergy because they either had severe eczema or were allergic to eggs. Each baby underwent a skin-prick test with a trace of peanut, which revealed any excess immune reaction. Allergic or highly reactive children were kept out of the study. The remaining infants were randomly assigned to get small doses of peanut butter in their diet at least three times a week or to avoid it completely.

Among 530 babies who had no reaction to the skin test, the peanut allergy rate at age 5 was 13.7 percent in the avoidance group and 1.9 percent in the peanut butter group. Among 98 other babies who had a slight or modest reaction to the skin test, 35.3 percent of those assigned to avoidance were allergic by age 5. Only 10.6 percent of such 5-year-olds eating peanut butter as babies were allergic. Lack presented the results February 23. The findings also appear in the Feb. 26 *New England Journal of Medicine*.

In 2000, the American Academy of Pediatrics released guidelines calling on parents to avoid giving peanut butter to babies who show any risk of allergy. But in 2008, those guidelines were rescinded because no clear evidence supported the policy unless an infant was clearly allergic. Since then, the issue has been up in the air, with some studies suggesting that peanut consumption might often be a better approach, Wood said. "The time is really right for this to lead to changes in recommendations, which were evolving without data."

Despite years of peanut avoidance by many families, peanut allergy rates in Western countries have risen in the last 10 years, reaching up to 3 percent. The key may lie in infants' diets, said study coauthor George Du Toit, also at King's College. While exclusive breastfeeding is recommended for the first six months, "less than 10 percent of countries achieve that. Young children are taking on complementary foods, weaning early," he said. "We now need to embed peanuts within that."

Writing in the *New England Journal of Medicine*, Hugh Sampson of the Icahn School of Medicine at Mount Sinai in New York City and Rebecca Gruchalla of the University of Texas Southwestern Medical Center in Dallas call the trial a "landmark" and endorse a skin-prick test for infants ages 4 to 8 months who are at risk of peanut allergy. If the test is negative, they say, start the baby on peanut butter at least three times a week for three years. Mildly positive children, like many in the study, should be given peanut butter initially with a doctor's supervision. ■

MEETING NOTE

Teens have higher anaphylaxis risk than younger kids

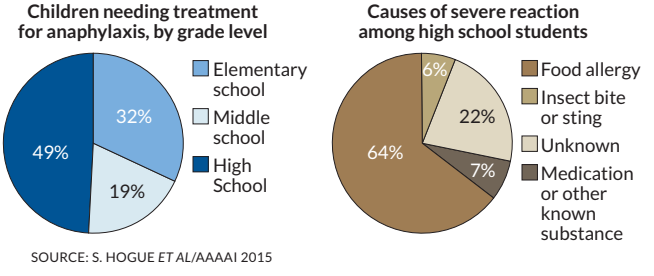
Although adolescents are better at taking care of themselves than young children, high school kids are more apt to experience an extreme allergic reaction. Data from 6,001 U.S. schools show that 724 of their students required treatment with an epinephrine injection during the 2013–14 school year. Nearly half of those kids were in high school, researchers reported February 23.

Food allergy caused the majority of these anaphylactic events, potentially fatal allergic reactions that require immediate treatment. Among students overall, insect bites or stings were the second most common ascertained cause. But the cause of many anaphylaxis episodes was a mystery, said Susan Hogue of RTI Health Solutions of Research Triangle Park, N.C., who presented the findings.

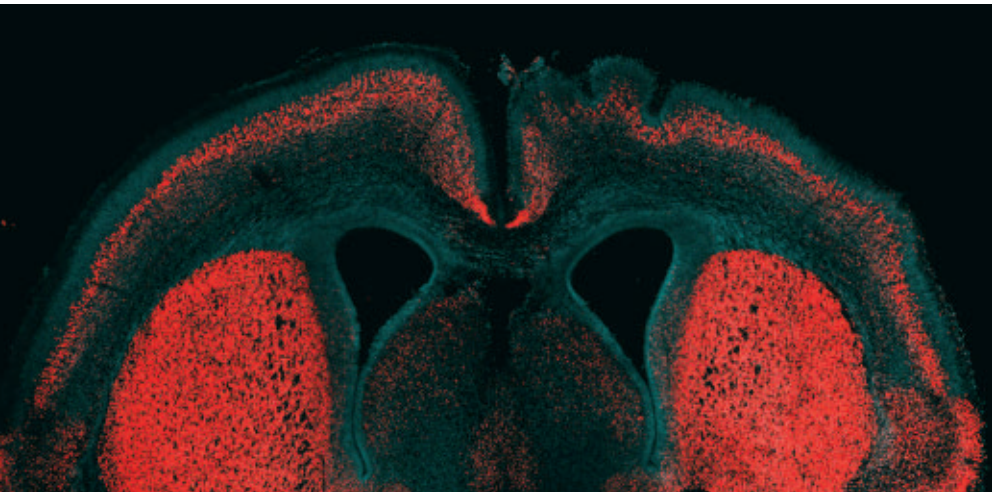
Coauthor Martha White of the Institute for Asthma and Allergy in Wheaton, Md., said several reasons might explain high-schoolers' higher anaphylaxis rates. Teens are less supervised than young kids, have more access to vending machines, often leave school for lunch and could therefore be more apt to sample unfamiliar foods.

The findings are part of a study to gauge the use of epinephrine injector "pens" in schools. The study was supported by EpiPen maker Mylan, which provided the devices to schools participating in the study. — *Nathan Seppa*

Anaphylaxis in schoolchildren



SOURCE: S. HOGUE *ET AL*/AAAAI 2015



A gene that only humans have can make the normally smooth outer layer of mouse brains develop folds similar to those in human brains (upper right center). The gene may have been important for the evolution of human brains.

M. FLORIO AND W. HUTTNER/MPI-CBG

GENES & CELLS

Genetic tweaks built bigger brains

Experiments in mice show how to grow a wrinkled cortex

BY TINA HESMAN SAEY

Human brains ballooned to about triple the size of their ancestors' thanks to a few genetic tweaks, new research suggests.

When scientists inject a gene found only in humans into the brains of mouse embryos, the normally smooth mouse brain develops the crinkles and folds reminiscent of wrinkly human brains, scientists report online February 26 in *Science*. The wrinkles are a sign that the brain's outer layer, or cortex, is growing.

That discovery closely follows a report from Duke University researchers who have found a genetic switch that boosts brain size. In mice, the human version of that switch produces a 12 percent larger cortex than a chimpanzee switch does, the team reports online February 19 in *Current Biology*.

Together, the two studies present some of the first genetic clues about how human brains tripled in size starting about 2 million years ago. Some scientists thought it could take many genetic changes for evolution to plump up the human brain, says Mary Ann Raghanti, a biological anthropologist at Kent State University in Ohio who was not involved in either study. These new findings suggest that relatively few changes were necessary to inflate brain size, she says.

The Duke team's findings provide evidence that pieces of DNA that regulate gene activity are important for shaping brain evolution. Called enhancers, these DNA bits help determine when during development, and in which tissues, a gene will turn on.

Developmental neurobiologist Debra Silver and evolutionary geneticist Gregory Wray and colleagues examined enhancers that are evolving faster in humans than in other primates. The team zeroed in on one called HARE5, which turns on a gene called Frizzled 8 in the brain during development.

Human HARE5 has 16 differences from the chimpanzee version that alter brain development, the team found.

In mice engineered to possess a copy of the Frizzled 8 gene, adding the human version of HARE5 made nerve cells grow faster than in mice given the chimp version. Mice with the human HARE5 developed a 12 percent bigger cortex than mice with the chimp enhancer — but that boost isn't enough to explain the entire explosion of human brain size, Silver says.

A gene called *ARHGAP11B* can also build bigger brains, say Wieland Huttner, a molecular and cellular biologist at the Max Planck Institute of Molecular Cell Biology and Genetics in Dresden, Germany, and colleagues. That gene is an imperfect copy of another gene and doesn't work like the original, the team reports in the *Science* paper. Duplicating DNA is one of evolution's favorite ways of creating genes with new functions, says Raghanti.

The gene was duplicated about 5 million years ago — after the common ancestor of modern humans and their extinct cousins Neandertals and Denisovans split from chimpanzees. Neandertals also had big brains. No Denisovan skulls have been found.

ARHGAP11B causes one type of primordial brain cell to switch to another type, Huttner and colleagues found. One part of the brain that makes new nerve cells in adults grew 50 percent thicker in mice that got a dose of the gene than in mice that didn't. Injecting the gene into mouse brains also caused cortex folding.

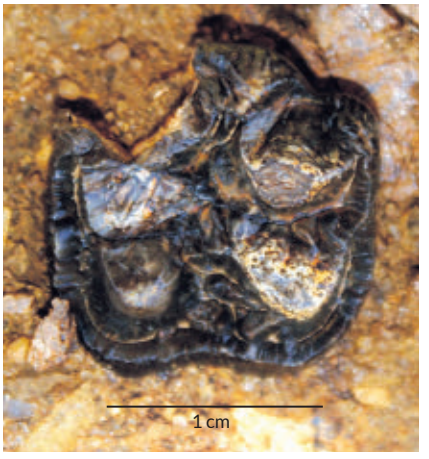
The studies are exciting, says evolutionary geneticist Evan Eichler of the University of Washington in Seattle, but are probably not the whole story of how humans got bigger brains. He's concerned about the timing: *ARHGAP11B* appeared about 5 million years ago, but brain size didn't really start to change in the human lineage until about 2 million years ago. "What the heck was it doing for 3 million years?" Eichler asks. The discrepancy suggests that other factors must have evolved during that time to spark the big-brain explosion.

In another recent study, James Noonan of Yale University and colleagues found that thousands of genes, some involved in making new brain cells during development, are more active in human brains than in mice or rhesus monkeys. The team mapped enhancers and other bits of DNA called promoters that regulate gene activity. In addition to brain size, genes involved in wiring the brain properly became more active in humans than in monkeys or mice, the team reports in the March 6 *Science*. The findings suggest that many tweaks were involved in the evolution of the brain. ■

LIFE & EVOLUTION

Hippo history extracted from fossil teeth

Fossil teeth found in Kenya help fill in holes in the history of hippopotamuses. The roughly 28-million-year-old teeth (one shown) belong to a newly identified hippo ancestor named *Epirigenys lokonensis*. This extinct species links the oldest known hippos in Africa with their earlier Asia-dwelling ancestors, Fabrice Lihoreau of Université Montpellier II in France and colleagues report February 24 in *Nature Communications*. Grooves in the teeth of *E. lokonensis* have similar patterns to grooves in the teeth of some older anthracotheres, extinct hippo and whale relatives that lived about 40 million years ago in what is now Southeast Asia. But the enamel on *E. lokonensis*' teeth is thicker and the points are blunter. The shape of the premolars is also more similar to that of hippo relatives that roamed Uganda about 21 million years ago. The teeth help explain how hippos got to Africa. The continent was isolated from other landmasses from about 110 million to 18 million years ago. Fossils suggest that about 35 million years ago, small groups of primates and anthracotheres started to migrate from Asia to Africa. *E. lokonensis*' existence in Africa 28 million years ago suggests that hippos are descendants of the first wave of anthracotheres — the earliest large land mammals — to invade Africa. To get to Africa, anthracotheres had to swim, suggesting that a semi-aquatic lifestyle evolved early in hippos' history. — *Ashley Yeager*



F. LIHOREAU/LPRP

Tails of luna moths deflect bat attacks

Those pretty green tails fluttering and whirling at the end of a luna moth's hind wings turn out to be pretty good defensive weapons in an acoustic war with predatory bats. As tips of a moth's tails whirl in two circles behind the wings, they reflect the echolocation pings that a bat uses to find and nab prey out of the air. That can trick bats into attacking the relatively expendable tails, or missing the moth altogether. Jesse Barber of Boise State University in Idaho and his colleagues report the finding in the March 3 *Proceedings of the National Academy of Sciences*. In lab experiments, big brown bats struck at the tails of luna moths (*Actias luna*) instead of other body parts 55 percent of the time. When researchers trimmed tails off the moths, tailless moths were almost nine times as likely as intact moths to be caught by a bat. For the moths, the tails seem to be about as effective as the better known moth defense against hungry bats: ears to detect the echolocation pings of an incoming predator. The tail doesn't seem to add noticeable oomph to flight, Barber and colleagues conclude. Yet the swirly motion does seem to enhance its allure as a misleading target to bats. Of the four times that long tails have evolved in the whole family of saturniid moths, the little cupped spatulas at the tips of the tails that enhance twirling have evolved too. — *Susan Milius*

HUMANS & SOCIETY

Wheat reached England before farming

Hunter-gatherers living on England's southern coast imported wheat 2,000 years before agriculture sprouted in the British Isles, a new study suggests. Trading among hunter-gatherers and farmers laid the groundwork for agriculture's spread across Northwest Europe, propose Oliver Smith of the University of Warwick in England and colleagues. Until now, researchers have contended that migrating farmers rapidly sent European hunter-gatherers packing or gradually converted them to an agricultural lifestyle (*SN: 5/17/14, p. 26*). DNA extracted from soil at a roughly 8,000-year-old site called Bouldnor Cliff, now submerged off the Isle of Wight, matches that of wheat domesticated earlier in or near what's now Turkey, the scientists report in the Feb. 27 *Science*. Farmers there had domesticated wheat and several other plants by 10,500 years ago. Crop-growing started closer to England around 7,600 years ago in Western France, 400 hundred years after wheat had reached Bouldnor Cliff. Cultivation in England began much later, about 6,000 years ago. Excavations by divers at Bouldnor Cliff have recovered stone tools and other remnants of ancient human activity. Smith's team obtained DNA from four radiocarbon-dated soil samples at Bouldnor Cliff. A peat bog had sealed off the site before rising seas covered it shortly after 8,000 years ago. The scientists found no evidence that wheat was grown at Bouldnor Cliff. — *Bruce Bower*

ATOM & COSMOS

Stellar nursery gives birth to quadruplets

A young stellar foursome is giving astronomers a rare peek at how stars form. New images reveal a quadruple star system, the youngest known, emerging from a cocoon of interstellar gas. The discovery shows how systems of two or more stars, which make up over half the stars in the galaxy, can arise out of threads of gas that break apart. The stellar nursery contains one previously known star surrounded by three clumps of gas collapsing under their own gravity. Over the next 40,000 years or so, the three knots of gas will turn into young stars, creating a gravitationally bound quadruple star system, researchers report in the Feb. 12 *Nature*. Eventually, two of the stars will probably drift away, leaving the remaining pair as a binary star system. Jaime Pineda of the Max Planck Institute for Extraterrestrial Physics in Garching, Germany, and colleagues discovered the quadruplets with the Very Large Array radio observatory in New Mexico. The stellar nursery sits about 820 light-years away in the constellation Perseus. Binary stars are ubiquitous in the galaxy, but astronomers don't fully understand how they form. — *Christopher Crockett*

Watch a video of luna moths evading bats at **bit.ly/SN_lunamoths**

Aggression Avenue

Tracing how the brain is wired for violence

By Susan Gaidos

The fruit fly *Drosophila* (above) has attack-promoting nerve cells similar to some in mice and birds. Studying such cells might help scientists better understand human aggression.

EYE OF SCIENCE/SCIENCE SOURCE

Male mice in David Anderson's Caltech laboratory are typical rodents. Mellow most of the time, they'll defend their cages if provoked — chasing male intruders away. The mice will lunge and nip until one admits, paws up, social defeat. Rarely do they actually hurt each other.

But with the flick of a switch, Anderson's team can convert an ordinary lab mouse into a vicious brute that won't back down. Like Bruce Banner morphing into the Hulk, the mouse seems to have no choice but to let the monster spring forth, inflicting bite after bite on its cowering victim.

To draw out the animal's natural aggression, scientists activate a small group of nerve cells, or neurons, identified by Anderson's group and others, that act as a control center for aggressive behavior. Turning on those brain cells instantly increases a mouse's appetite to fight.

During these confrontations, the scientists map the physical and chemical connections among the cells to track the neural roots of violent behavior. Such rodent scuffles may seem a far cry from, say, the aggression of a school bully or cold-blooded killer. But researchers think some of the same circuits in the brain may be involved.

The brain's attack neurons reside in an area called the ventromedial hypothalamus, a region long linked to aggression in animals. Scientists began closing in on those neurons in 2011 in the process of discovering a way to transform docile mice into angry goons.

Since then, researchers have narrowed the list of neurons involved. Last May in *Nature*, Anderson's team described a small group of neurons that specifically escalate aggression. Nirao Shah's team at the University of California, San Francisco independently identified the same neurons.

"In 2011, we knew the neighborhood where these neurons lived, but we didn't know the exact houses or streets in that neighborhood," Anderson says. "We now know that."

This aggression hub in the hypothalamus doesn't work alone. It is part of a network of brain structures. From this neighborhood, where attack behavior is organized, each neuron connects to others throughout the brain to produce the features associated with fighting: a racing heart, increased metabolism and the muscle movements

involved in charging or biting. By studying nerve signals coming into the hub and tracking those moving out, scientists aim to build a circuit diagram, showing how the brain puts the entire body into a fight state — or holds aggressive impulses in check.

Anderson calls this hub "our beachhead into the brain for studying aggression."

Details of the map are still emerging. In some areas, neurons related to aggression differ in males and females. And neurons clustered in a second brain region of the mouse also induce an attack when activated, scientists reported February 3 in *Cell Reports*. These cells incite aggressive behavior in males and females alike.

Experiments in flies and birds reveal attack-promoting neurons in brain regions similar to those found in mice. Such studies of attack centers in animals promise a better understanding of how aggression is organized and produced in the brain: Is it distributed diffusely or controlled by a few key nodes? Because the human brain is wired pretty much the same as the mouse's, the studies may lend insight into human aggression as well.

Bad neighborhoods

Occasional outbursts of aggression are common, even normal, in animals from birds to mice to humans. Faced with a genuine threat, most creatures will raise their voice or take physical action to fend off an attack.

Neurons that elicit attack behaviors sit in the hypothalamus — a region in the center of the brain. Formed by dozens of small clusters of cells, the hypothalamus governs many basic functions such as feeding, metabolism, body temperature, thirst, fatigue and sleep. It also regulates basic drives, such as mating and aggression.

In the 1920s, Walter Hess at the University of Zurich found that an electric burst to the hypothalamus could send cats into a fury, arching, hissing and clawing nearby objects. He was awarded a Nobel Prize in 1949 for his work. Studies in the 1980s confirmed that the hypothalamus is also a center for rage in rats. Still, the precise location of attack-promoting neurons, and their mode of action, remained a mystery. Without the tools to probe specific sets of cells in this hard-to-reach region, studies stalled.

In recent years, though, new technologies have made it possible to study individual brain cells in animals, so scientists could take a closer look at the role of the hypothalamus in aggression. One way to see where neurons are most active during a task is to track the activity of *c-fos*, a gene that produces proteins in response to neuronal activity.

With another technique, called optogenetics, researchers engineer individual rodent brain cells to make them controllable by light (*SN: 1/30/10, p. 18*). Scientists deliver a gene that encodes a light-sensitive protein into the cells of interest. The engineered neurons can then be activated or "turned on" to communicate with other neurons simply by shining colored laser light onto the cells. Scientists can stimulate or shut down specific cells and then observe the animal's behavior.

Using these techniques, Anderson's group began probing cells in the hypothalamus five years ago. Dayu Lin, then a postdoctoral researcher in Anderson's lab, quickly zeroed in on a small area that became active when male mice started to fight. This part of the hypothalamus, the ventrolateral area of the ventromedial hypothalamus or VMHvl, is made up of roughly 10,000 nerve cells.

"It's not a lot of real estate in the brain, but apparently it is a very critical area," says Lin, now at New York University. Her study, published in 2011 in *Nature*, also revealed a surprise: The small part of the hypothalamus linked with aggressive behavior is also associated with mating behaviors. In some instances, the same neurons activated during aggressive encounters appear to be activated when the animals mated.

Anderson's team is looking for similar attack–mating connections in flies. In January 2014, his team reported in *Cell* on a tiny group of neurons that promote aggression in male fruit flies but don't exist in females. These neurons are active when male flies jockey for position on a food dish or fight other males to win access to females. Because flies have a simple nervous system, activating only three to five neurons of their total of 100,000 brain cells sends them lunging at nearby targets. Anderson's team is now investigating whether those neurons also play a role in mating, as they do in mice.

Whether VMHvl neurons are multitaskers, busily working to promote both sex and violence, or if they just happen to occupy the same general brain area, is not yet known. Even though these behaviors are opposing forms of social interaction, both are driven by chemical signals, called pheromones, and share common features such as sniffing and close physical contact.

"To an untrained eye, when you see two mice engaging in mating and fighting, it's often difficult to tell the difference," Anderson says.

Aggression and mating share another feature in

"To an untrained eye, when you see two mice engaging in mating and fighting, it's often difficult to tell the difference."

DAVID ANDERSON

animals: The behaviors are hard-wired from birth.

"The first time a male fly encounters a female fly, it will court her. The first time he encounters a male fly, he will engage in aggression with that fly," Anderson says. The same holds true for mice: Aggression requires no formal training.

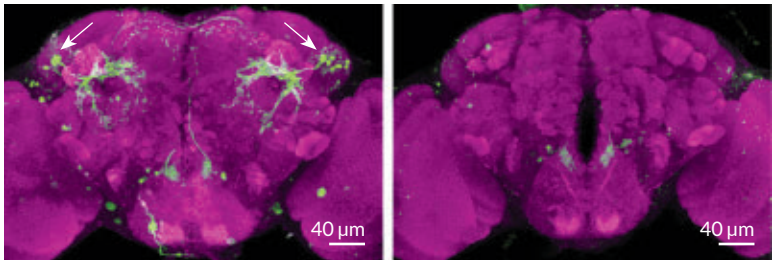
Given that the drive to express aggression is built into the brain, scientists say it's no surprise to find that there's a hub, or maybe several, directing behavior to make animals respond in the right way at the right time. Though researchers have yet to work out a flow chart, a chain of command might include a key command center with connections to nearby hubs and distant brain regions. The network would also connect to sensory neurons, which bring cues from the outside world (odors, sight, sound) to the hub to guide behavior, and to the brain's motor regions to relay information needed to carry out actions.

From lover to fighter

Scientists are not looking for a single trigger to explain violent outbursts. Aggressive behavior, animal or human, is the outcome of not just the physical circuitry, but also brain chemistry, genes and a changing environment. Even within the VMHvl hub, there is much complexity. In this part of the hypothalamus different types of neurons do different jobs, relaying messages for mating, fighting and fear.

To resolve which neurons do what, Anderson's group pored over the Allen Brain Atlas, an online catalog that maps gene activity in the adult mouse brain. In looking for genes that control the VMHvl aggression hub, the scientists identified a group of cells marked by the presence of a receptor for the hormone estrogen. Follow-up studies showed that these neurons were most likely to be active when the animal was engaged in fighting.

The scientists then genetically modified mice by inserting light-sensitive proteins into those neurons. Surprisingly, by adjusting the intensity of light researchers could change the animal's behavior. Activating the cells by turning the light up to high intensity prompts mild-mannered males to bite and claw nearby targets — even a mate or a castrated male, animals normally not perceived as threats. Turn down the light to low and instead of attacking targets, the mouse mounts them, a first step in mating behavior. Toggling the switch from low to high prompts animals to switch from lover to fighter in seconds.



Bully cells A tiny cluster of neurons in male fruit flies (left, arrows) spurs them to square off against other male flies in the presence of females or food. These aggression neurons don't exist in the brains of female flies (right).

KENTA ASAHINA *ET AL*/*CELL* 2014

Anderson says the findings, published last May in *Nature*, show that aggression neurons in the VMHvl control multiple phases of a social interaction, from sniffing and getting to know you, to touching and mating, to all-out attack. His group continues to alter activity in the cells in search of the control mechanism behind this fine-tuning, along with studying estrogen's role in the mix.

Hormones are the body's signaling molecules. Researchers have long known that the sex hormones — testosterone, estrogen and progesterone — have profound effects on the brain. They influence brain development in the young and memory in the old. Though viewed as the he-man hormone that controls aggression, testosterone gets converted into estrogen in the male brain. The enzyme aromatase handles this conversion.

In 2009, Shah's group showed how estrogen "masculinizes" brain circuitry during development, predisposing boys to be boys by setting up scores of aromatase-producing neurons. Females have these neurons too, but in smaller numbers.

Since then, Shah's group has probed the neural circuitry of male and female mice looking for differences that might explain sex-specific behavior. Even in mice, aggressive behavior differs dramatically between the sexes. Male mice forcefully stake out territory and constantly scuffle to maintain control. In the lab, a male mouse dropped into another male's cage is immediately pummeled and chased away. Females do not perpetrate such attacks; they generally limit their aggression to protecting their young.

In addition, there are big differences in how males and females fight. Males, for example, typically attack other males by moving toward the flank region, or side. They may also box and wrestle. Females attack intruders by moving straight for the neck or the genital region. While both fight styles aim to ward off attacks, they employ different movements and strikes.

"It's like one guy is using kung fu and the other animal is using tae kwon do," Shah says. To study the neural pathways that control these

sex-specific behaviors, Shah's group has uncovered a handful of genes that are influenced by sex hormones in the brain. By turning off these genes, one by one, his group can tease apart a hormone's influence on individual behaviors.

Through this process, Shah and colleagues identified a population of about 2,000 neurons linked to male aggression — roughly the same group of VMHvl cells identified by Anderson's team. The findings, published in 2013 in *Cell*, showed that, along with estrogen receptors, most of the cells harbor progesterone receptors. Progesterone helps control sexual behavior and pregnancy in females, but is also produced in males. It's not yet clear that receptors for either estrogen or progesterone play a direct role in controlling aggressive behavior, Shah says. For now, the receptors serve as a marker he can use to isolate and manipulate the cells.

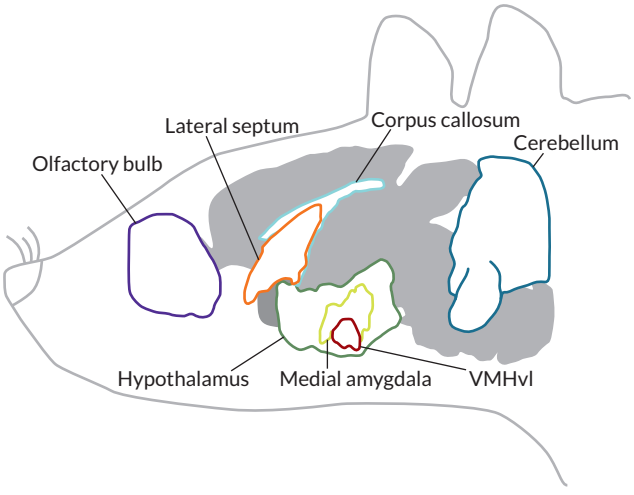
Forging the path

In recent months, scientists have identified groups of aggression neurons inside the medial amygdala, a brain structure that processes fear and other emotion. Last September in *Cell*, Anderson's group described a population of amygdala neurons that, when activated by optogenetic techniques in male mice, can either trigger attacks (at high levels of light) or produce mounting behavior (at lower light levels), just like the neurons in the hypothalamus.

Anderson says the amygdala neurons that promote attacks may be part of a circuit that feeds in — directly or indirectly — to the "attack" neurons in the VMHvl. His group is now searching for anatomical pathways between those structures.

In February, Shah's team identified a group of aromatase-producing neurons in the amygdala. These cells are the first in the aggression circuit shown to influence both male and female aggression, Shah says. His group is working to identify connections going to and from this region to see if aggression-related neurons are wired into different circuits in females than in males.

As details of the aggression circuit emerge, scientists in these labs and others are designing experiments to determine how, or if, environmental cues feed into the circuit to help control, or resist, impulses to fight. In her NYU lab, Lin uses optogenetic tools to trace signals entering the middle of the VMHvl from a brain area called the lateral septum. In mice, the lateral septum is sandwiched between the cingulate cortex and the nucleus accumbens, near the front of the hypothalamus. The lateral septum has physical links to the hypothalamus, with projections leading directly to the VMHvl.



Where to? In the mouse brain, the VMHvl of the hypothalamus and the medial amygdala are crucial to aggression. They connect by neuronal pathways to other brain regions including the lateral septum, the cerebellum (for motor coordination) and the olfactory bulb, which communicates with the vomeronasal organ outside the brain (for threat perception). SOURCE: ALLEN BRAIN ATLAS

Studies in rodents show that damage to the lateral septum causes animals to become hyperaggressive. Because cells in this brain area produce inhibitory neurotransmitters that slow down neurons, scientists believe that, under normal circumstances, the structure serves to inhibit aggressive impulses.

"The lateral septum seems to be perfectly positioned to relay those environmental and experience-related cues to moderate the output of the social behavior," Lin says.

As studies progress, questions about how the brain controls aggression may get back to even more basic questions, such as: How can people actively control their aggressive impulses? Or create a safer world?

Anderson says biological studies of violent behavior are often hampered by legal and social concerns. Could individuals be unfairly stigmatized if they are wired for violent tendencies? Would knowledge of aggression's biological roots make it hard to convict the pathologically violent, who might claim, "My cells made me do it"?

"On the one hand, we're terribly concerned about violence. Every time there's another school shooting, people want to know why there's an epidemic of violence in this country," Anderson says. "At the same time, people are very reluctant to get to the biological roots of violence and aggression. But if we knew something more about it, we might be able to prevent some of these tragic events." ■

Explore more

- Annegret Falkner and Dayu Lin. "Recent advances in understanding the role of the hypothalamic circuit during aggression." *Frontiers in Systems Neuroscience*. September 25, 2014.

J. HIRSHFELD

To watch mice fighting mice and flies attacking flies, visit bit.ly/SN_aggression

FEATURE

Eyes on the INVISIBLE PRIZE

Sam Ting won't be rushed to solve the mystery of dark matter

By Andrew Grant

In the near vacuum of outer space, each rare morsel of matter tells a story. A speedy proton may have been propelled by the shock wave of an exploding star. A stray electron may have teetered on the precipice of a black hole, only to be flung away in a powerful jet of searing gas.

Since 2011, the International Space Station has housed an experiment that aims to decipher those origin stories. The Alpha Magnetic Spectrometer has already cataloged more than 60 billion protons, electrons and other spaceborne subatomic particles, known as cosmic rays, as they zip by.

Other experiments sample the shower of particles produced when cosmic rays strike atoms and molecules in Earth's atmosphere. But the spectrometer scrutinizes pristine cosmic rays — some of which have traveled undisturbed over millions of light-years — from its perch some 400 kilometers above Earth. The Alpha Magnetic Spectrometer is by far the most sensitive cosmic ray detector ever to fly in space, and with a price tag of about $2 billion, it's also the most expensive.

The detector's unprecedented particle census could unmask the identity of dark matter, the mysterious, invisible substance that is five times as abundant in the universe as ordinary matter. Some of the cosmic rays snatched by the instrument may have been produced by particles of dark matter colliding and annihilating each other in the center of the galaxy.

The spectrometer could also help scientists determine why planets, stars and other structures in the universe are made of matter rather than antimatter. Particles of antimatter have the opposite charge as their matter counterparts but are identical in nearly every other way. It's uncertain why most of the antimatter particles disappeared just after the Big Bang 13.8 billion years ago. Physicists would love to discover primordial antimatter to test their theories on what hastened its demise.

Designed to detect cosmic rays, the Alpha Magnetic Spectrometer cruises above Earth on the International Space Station.

NASA

Nearly four years into the mission, the Alpha Magnetic Spectrometer is delivering precise data and arguably providing a few hints about the nature of dark matter. But it's unclear whether the mission will ever deliver on its ambitious goals. Cosmic rays are charged particles that get whipped around by magnetic fields, so they don't travel in straight lines and cannot be traced back to their source. To pin the origin of particular cosmic rays to dark matter, scientists will have to rule out every other possible explanation. Critics say the chances of identifying dark matter are very slim. And finding primordial antimatter, they say, is nearly impossible.

Such criticism barely registers with the mission's leader, particle physicist Samuel Ting. The 79-year-old Nobel laureate has made a career of designing elegant experiments and, despite frequent opposition, successfully lobbying to get them built. Then he has patiently collected and analyzed data, meticulous to the extreme, before revealing the often-impressive findings. Though results may come later than most scientists would prefer, Ting is confident that conducting a powerful particle physics experiment in space will expand scientists' understanding of the cosmos.

Full focus

Ting's home base these days is at CERN, the European physics laboratory outside Geneva that partially funds the Alpha Magnetic Spectrometer and is home to the mission's command center. But on one afternoon in December, Ting is at MIT, where he still runs a lab. His office is housed in a building marked with a capital J that honors his Nobel Prize–winning discovery, the J particle. The alleged reason for Ting's U.S. visit was to meet with a contractor to discuss renovating his Cambridge, Mass., home. But the contractor confab was brief. For Ting, matters outside of physics take a backseat.

"You really can't get into this field without thinking this is the most important thing in your life," Ting says.

Two high-definition monitors on his office wall reinforce his obsession. One shows a live feed from the space station, a grainy black-and-white image capturing the spectrometer and our imperceptibly spinning planet below. The other screen plays a computer reconstruction of the instrument in action. In nearly real time, cosmic rays pass through its magnet, triggering a slate of sensors that determine the particles' identity, energy and trajectory.

Ting doesn't have a background in astrophysics, but he has plenty of experience sorting through a glut of particles to find really cool stuff.

He pulls up a 1965 *New York Times* article on his computer. The article describes Ting's first major discovery, when he, Leon Lederman (who won the 1988 Nobel Prize in physics) and colleagues produced and detected antimatter nuclei for the first time. (A team at CERN made a similar discovery soon after.) It's difficult enough to observe single particles of antimatter because they disappear in a burst of energy when they encounter ordinary matter. Ting and Lederman managed to observe bound pairs of antimatter particles, called antideuterons, in a particle accelerator at Brookhaven National Laboratory in Upton, N.Y.

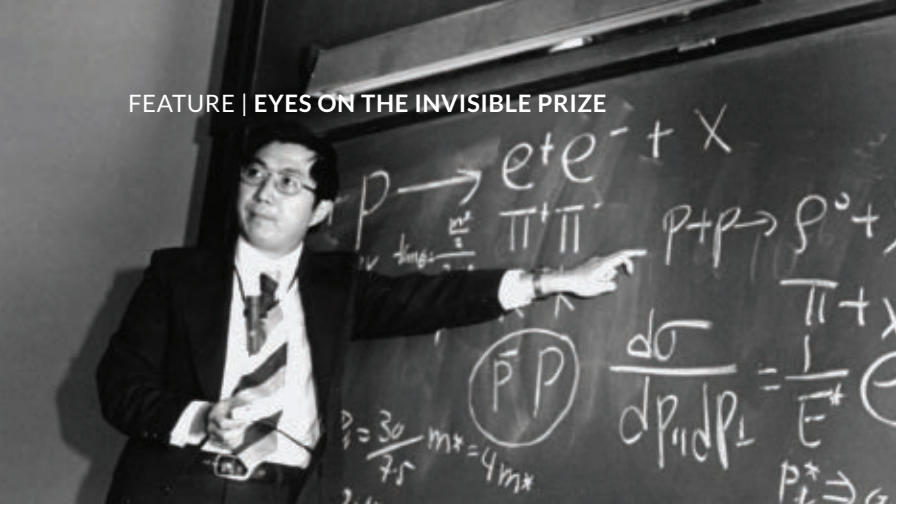
Ting's childlike curiosity quickly comes across as he describes the possibility that antideuterons and other large chunks of antimatter, relics of the first moments after the Big Bang, could be drifting in the cosmos, waiting to be found. But beneath the inquisitiveness is also an extreme confidence, even an arrogance, that he alone knows the way to probe the big questions.

Those qualities were on display in the early 1970s when Ting became interested in quarks, tiny parcels that compose such particles as protons and neutrons. Physicists had proposed and discovered evidence for three kinds of quarks. But Ting, eager to unravel every detail about matter's makeup, joined a group of physicists who wondered whether there were other quark varieties. He proposed colliding particles at high energies, which would create short-lived matter that ultimately decayed into electrons and their antimatter counterparts, positrons. By analyzing the electrons and positrons, he could determine the composition of the intermediate particles.

Ting says many physicists scoffed at his proposal; they believed that the three quarks could explain all the more complex particles in physics. Multiple labs turned him down before Brookhaven let him give it a try.

In the summer of 1974, Ting and his team saw convincing signs of a new subatomic particle with an unusual composition. But Ting refused to release the data until he was sure everything was correct. He split his team into two groups that independently analyzed the data again and again. Only in November of that year, when a colleague at a meeting told Ting that particle physicist Burton Richter had seen the same signal at the Stanford Linear Accelerator Center, did Ting share his finding. The confirmation of a fourth quark, the charm, embedded in a particle that Ting called

> "You really can't get into this field without thinking this is the most important thing in your life."
>
> **SAM TING**



Distinguished career Particle physicist and Nobel laureate Samuel Ting, pictured in 1974 (above) and in 2012 (opposite page), has studied the fundamental components of matter and antimatter (see timeline).

J and Richter called Psi earned Ting a share (with Richter) of the 1976 Nobel Prize in physics. Ting's experimental design skill, combined with large doses of meticulousness, smarts and stubbornness, had netted him the ultimate physics honor. He was 40 years old.

From there, Ting kept pursuing big projects. In the late 1980s, he organized a team to design a detector for the multibillion-dollar Superconducting Super Collider, an 87-kilometer-around particle accelerator slated for construction near Waxahachie, Texas. Ting wanted to build a $750 million instrument; the U.S. Department of Energy said the detector should not cost more than $500 million. So Ting quit. "He was very determined to do it his way," says Gary Sanders, a high-energy physicist and former Ting graduate student who was part of that team.

In 1993, Congress dealt American physicists a devastating blow by canceling the Super Collider. Ting, however, had moved on. In 1994, he pitched perhaps the most ambitious project of his career.

Like his first major experiment, it would hunt for antideuterons and other antimatter nuclei. And similar to his Nobel-winning research, it would use electrons and positrons as probes to identify undiscovered parent particles. Except instead of sorting through shrapnel created in carefully orchestrated particle collisions, he wanted to go after particles produced naturally in the universe. The Alpha Magnetic Spectrometer experiment would collect and analyze particles in space.

Both NASA and the Department of Energy, the same agency that rejected Ting's plan for the detector in Texas, pledged their support.

From lab to liftoff

Scientists have studied cosmic rays for a century in hope of learning about the objects that produce them. But Ting's proposal offered the rare chance to create a robust census of cosmic rays from well above Earth's meddlesome atmosphere. Most previous experiments took place on balloons, which fly only briefly and don't leave the atmosphere, or on the ground, forcing scientists to analyze cascading showers of particles triggered by cosmic rays striking atoms in the atmosphere.

Those past experiments still delivered some tantalizing results. In 1997, the High-Energy Antimatter Telescope, or HEAT, a cosmic ray detector tethered to a high-altitude balloon, revealed an unexpectedly high concentration of positrons in space. At the time, physicists didn't know of many processes in the universe that could produce positrons, so theorists quickly came up with some ideas. The most intriguing possibility was that the positrons were created by particles of dark matter in the galaxy. Though the dark matter particles would be invisible, they would occasionally collide and annihilate each other to produce gamma radiation and detectable particles, including electrons and positrons. If these dark matter theories were correct, then a precise measurement of cosmic ray positrons would enable physicists to pin down the nature and mass of dark matter particles.

But dark matter wasn't the only explanation. Other theorists proposed positron-forming mechanisms that have far less relevance for deciphering the universe. Atop the list were pulsars — dense, rapidly spinning cores left over after massive stars explode. A pulsar's rapid rotational speed generates an intense electromagnetic field strong enough to rip electrons from its surface. Those electrons interact with photons and create pairs of electrons and positrons. Calculations suggested that just one or two pulsars, which are difficult to detect, within hundreds of light-years of the solar system would be enough to litter Earth with positrons.

Despite the intriguing quandary exposed by HEAT, some scientists doubted that the Alpha

ENERGY.GOV/FLICKR

1965 Ting and colleagues create and detect first antimatter nuclei

1974 Ting's team discovers first particle, called J/Psi, containing charm quarks

1976 Nobel Prize in physics goes to Ting and Burton Richter for finding J/Psi

1991 Ting quits team building detector for Superconducting Super Collider

1994 Ting pitches idea to search for antimatter from space

1997 Another project reveals unexpectedly high concentrations of positrons from space, supporting Ting's idea

1998 Alpha Magnetic Spectrometer prototype tested on space shuttle

2003 *Columbia* explodes, throwing space shuttle program into turmoil

2005 NASA rescinds offer to transport AMS to space station

2008 President George W. Bush signs bill so AMS can get to space station

2011 AMS reaches space station

April 2013 First results from AMS released

Magnetic Spectrometer could add much to the positron origin debate or resolve any big physics mysteries. But Ting was determined to see his project fly. He assembled a 16-country collaboration to divide the work and the ballooning costs. When the 2003 explosion of the space shuttle *Columbia* led NASA to rescind its offer of a ride to the space station, Ting lobbied members of Congress, teasing at the wonders that could be hidden in cosmic rays and stressing the International Space Station's not-so-stellar reputation for housing serious science.

"If you told Sam that to get what he wanted he had to win the Indy 500, he'd become the world's best race car driver," says Richard Milner, the director of MIT's Laboratory for Nuclear Science, who oversees Ting's group. Ting wouldn't let up on government officials in Washington, even as many of his collaborators focused on other projects.

He was very persuasive, says Kay Bailey Hutchison, at the time a U.S. Senator from Texas. She says Ting convinced her and others that the mission was worth the cost and safety concerns of extending the beleaguered shuttle program. "He's such a visionary," she says. She was inspired enough to switch appropriations subcommittees to find funding for the project. In October 2008, President George W. Bush signed a bill adding shuttle flights so that the Alpha Magnetic Spectrometer would hitch a ride on one of them. "Without [Ting's] absolute unwillingness to give up, we would not have gotten it," Hutchison says.

By the time Ting's brainchild reached the space station in May 2011, a couple of space-based cosmic ray experiments had beaten his spectrometer to the punch. In 2008, PAMELA, a cosmic ray detector attached to a Russian reconnaissance satellite, revealed the same positron excess hinted at by HEAT. NASA's Fermi Gamma-ray Space Telescope, which also carries a cosmic ray detector, came up with similar results in 2011. Neither probe discerned the source of the positrons, however.

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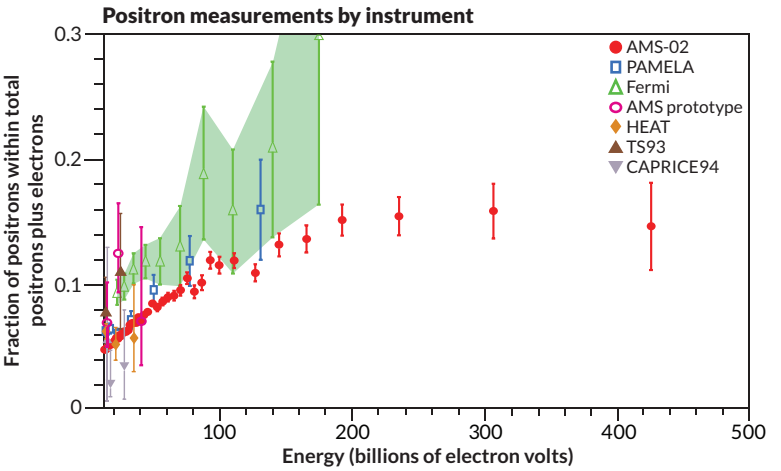
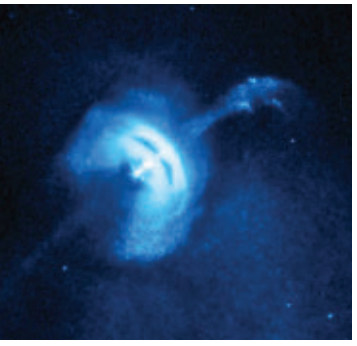


Positron puzzle The positron measurements (as a fraction of the total number of positrons and electrons) made by the Alpha Magnetic Spectrometer (AMS) are shown with solid red circles in this graph. Measurements made by previous instruments (see legend) had much larger margins of error, as indicated by the lines above and below each data point. SOURCE: L. ACCARDO *ET AL/PHYS. REV. LETT.* 2014

Ting's instrument began its cosmic ray survey almost immediately after installation, collecting as much data in one day as PAMELA did in 50. It sifted through positively charged particles, most of which are protons, and picked out the more valuable positrons. Ting, true to form, took his time before releasing the first results. "I doubt in the next 20 years anyone will be able to repeat the experiment," he says. "There's nobody to check us. It's of the utmost importance to get it correct."

Ting broke his silence with a news conference at CERN in April 2013. After again employing two separate teams to comb through the data, he confirmed the positron excess detected by HEAT, PAMELA and Fermi (*SN: 5/4/13, p. 14*). Analyzing the properties of 6.8 million positrons and electrons, Ting's team found that the number of positrons keeps rising as the particle energies increase. The clear excess of positrons, Ting said, reinforces that something relatively nearby must be producing them. He pushed the dark matter explanation but admitted it was not the only possibility.

Ting returned for another news conference in September. This time, after poring over 10.9 million positrons and electrons, Ting's team pinpointed the energy, about 275 billion electron volts, at which the concentration of positrons stops increasing (see graph above). That's an interesting number, says Peter McIntyre, a high-energy physicist at Texas A&M University in College Station, because it indicates that the mass of hypothetical dark matter particles limits the energy of the positrons they can produce. Theorists could use the peak positron



	Dark matter	Pulsar
What is it?	A form of matter that accounts for most of the mass in a galaxy but does not consist of the ordinary kind of matter found on Earth.	A dense, rapidly spinning remnant of a star that was initially much more massive than the sun.
How would it produce positrons?	In theory, two dark matter particles can collide and annihilate each other to produce electrons and positrons.	The collision of photons with speedy electrons ripped from a pulsar's surface by intense electromagnetic fields produces electrons and positrons.
What are the implications?	Finding positrons from dark matter would help scientists to determine the type and mass of dark matter particles, resolving a decades-long mystery.	Positrons from pulsars would reveal something about particles that pulsars create. But it would not lead to big-picture understanding of the universe.

Pulsar mystique
Pulsars, like the Vela pulsar located about 1,000 light-years away, are rapidly spinning dense cores of former stars. Nearby pulsars may produce the unexplained excess of positrons detected by the Alpha Magnetic Spectrometer and other experiments.

energy to estimate dark matter's mass. But again, the experiment did not come close to proving that dark matter actually produced the positrons.

In fact, some physicists argue that the Alpha Magnetic Spectrometer, despite its unmatched particle-detecting prowess, can never definitively distinguish between dark matter annihilation, pulsars or a yet-to-be-discovered process that might be producing those surplus shards of antimatter.

"A pulsar could explain any observation that AMS could ever make," says Gregory Tarlé, a particle astrophysicist at the University of Michigan in Ann Arbor. No matter what the positron data, physicists will not be able to definitively isolate the alleged signal of dark matter, he argues.

Katherine Freese, a theoretical astrophysicist at the Nordic Institute for Theoretical Physics in Stockholm, agrees that conclusively proving dark matter from positrons will be very difficult. "My bet is on pulsars," she says.

Other experiments also suggest that AMS has a slim chance of making a compelling case for dark matter. In a study posted online in January at arXiv.org, physicists pored over Fermi telescope measurements to look for gamma radiation, which should also be produced when dark matter particles annihilate each other. The data ruled out most dark matter collision mechanisms proposed by theorists. And in December, scientists with the Planck satellite announced that their survey of the universe's most ancient light revealed no signs of detritus from colliding dark matter, which if self-annihilating now also should have been when the cosmos was young (*SN: 12/27/14, p. 11*).

Ting says he pays about as much attention to other experiments as he does to his critics. He monitors the scientific literature, but doesn't put much stock in blanket conclusions based on one set of data. "I learned a long time ago: Only look at your own experiment," he says.

He expects to learn more by studying positrons at higher energies. If the mass of a dark matter particle is, say, one trillion electron volts, then it probably wouldn't produce positrons with more than a quarter of that energy. So if the positron concentration falls off a cliff after the newly identified peak, Ting says, that would suggest a dark matter origin. Pulsars, on the other hand, should produce positrons with a spectrum of energies that wouldn't drop so precipitously.

Within the next year or two, the AMS team will release its first analysis of antiprotons, antimatter particles that Ting says are too heavy to be manufactured by pulsars but should be produced in dark matter collisions. Ting calls the preliminary results "intriguing." But of course, he won't offer more until all the cross-checks are complete.

He's confident that future measurements will allow him to definitively pin down the origin of positrons, whether from dark matter or something else.

Even if the dark matter picture remains muddled, there is a possibility that AMS will detect primordial antimatter. One of the biggest mysteries in physics is why matter won out in a universe that presumably began with equal parts of matter and antimatter. Ting hopes to find complex antimatter — perhaps antihelium (two antiprotons and two antineutrons) or antideuterons — that was forged just after the Big Bang. Tarlé and other scientists say the chances of detecting these antinuclei are extremely low because the antimatter would have to navigate through the matter-rich galaxy and solar system without being destroyed.

Ting is undeterred. Gathering insights about the cosmos takes time. Anticipating that funding will run as long as the space station operates, Ting simply wants to see what nature throws at him. "If you don't look," he says, "you do not know." ■

Explore more

- Alpha Magnetic Spectrometer: ams.nasa.gov
- CERN Topic: Antimatter: home.web.cern.ch/topics/antimatter

X-RAY: NASA/CXC/UNIV. OF TORONTO/M. DURANT *ET AL.*; OPTICAL: DSS/DAVIDE DE MARTIN

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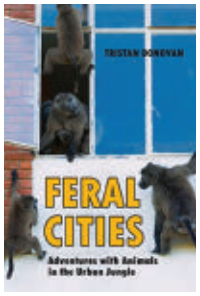

Feral Cities
Tristan Donovan
CHICAGO REVIEW, $16.95

BOOKSHELF

When animals invade human spaces

It's not really true that a baboon carjacked vehicles in Cape Town, South Africa. Yes, the big monkey liked to climb in, scaring people out of their cars and their wits. The baboon would rifle through the car for food, minding to check the glove box. But it didn't drive off.

Tourists were easy marks, getting out to take pictures and leaving car doors open. The seasoned baboon just outran people to their cars. Word got around to lock car doors when getting out to look at roadside baboons, but the creature soon learned that cars making a beeping sound often have unlocked doors.

In *Feral Cities*, journalist Tristan Donovan explores the conflict zone of cities and wild animals, and he seems to have a good time doing it. Observers were stunned to find a fox living on the 72nd floor of the unfinished Shard skyscraper in London, dining on scraps of workers' meals. Donovan says that this shouldn't have come as a surprise. While there is about one fox per square mile in rural England, in cities it's up to 14.

London's wildlife pales in comparison to that of Jaipur, India. It hosts thousands of rhesus macaque monkeys, and they're all thieves. Groups of monkeys raid fruit stands using a standard MO. One monkey distracts the tender. When the human gives chase, several others steal the goods. Monkeys are protected by the Hindu religion, so efforts to run them out of cities have been halfhearted. The result: The fraction of macaques in India that have had any contact with humans has increased from 15 percent in 1980 to 86 percent today.

Monkeys and other animals choose to live in cities for some of the same reasons we do — the dining is great. Bears, for instance, know that dumpsters contain cold pizza. But bears are drawn to more than pizza. For example, elk often show up in Banff, Canada, to calve their young in a safe neighborhood and eat up gardens. Before long, the neighborhood goes south: Grizzly bears show up to hunt the elk.

Some transplants are easily spotted, such as parakeets in Brooklyn or boars in Berlin. But leopards are practically invisible urban denizens in western India. There, a biologist fitted a tracking collar on an old leopard that had survived a fall down a well. Over three months, the big cat moved through a settlement, crossed busy roads and railroad tracks, chased dogs down streets and passed through an industrial park just outside Mumbai — without being reported by anyone.

Urban ecology is a new area of science that still harbors secrets (*SN: 1/10/15, p. 18*). Cities are "the least understood ecosystems on the planet," Donovan says. "They are places where much of what we think we know about the natural world doesn't apply." — *Nathan Seppa*

The Modern Savage
James McWilliams
THOMAS DUNNE BOOKS, $25.99

BOOKSHELF

Cage free may not be good enough

In today's zeitgeist, "factory farm" has become a profanity. For many consumers, the phrase conjures animal cruelty, with livestock crammed into pens and cages, barred from fresh air and sunlight and given feed loaded with drugs.

In revolt, many conscientious meat-eaters have adopted the mantra "know your food." The goal of this movement is to eat animals that have been treated humanely — given a "good life" — before their slaughter. Such livestock get a more "natural" upbringing, free to roam small-scale farms or get individual attention in backyard pens. But are "organic" and "cage free" products really better than industrial alternatives?

Not necessarily, writes historian James McWilliams, a vegan and an animal rights advocate. In *The Modern Savage*, he explores the pitfalls of small-scale and do-it-yourself meat production. Armed with gruesome anecdotes, he argues that amateur farmers can be incompetent. Animals on small farms may suffer from preventable diseases and injuries, botched slaughters and suburban predators such as dogs.

McWilliams also questions the idea that nonindustrial farms offer animals a more natural upbringing. Many organic farmers start off staunchly opposed to nose rings for their pigs, he points out. Common jewelry on industrial farms, these rings make it painful for a pig to follow its natural piggy tendency to root. Yet, he writes, those same organic farmers can quickly cave after Wilbur makes a mud pit of pasture and flower beds alike.

Very little data exist on the severity or prevalence of problems on small farms. (One exception: Studies have repeatedly found higher levels of germs and disease on small and organic farms than at industrial outfits.)

To McWilliams, any amount of animal suffering is problematic. In the book, he goes even further, arguing that there's an ethical contradiction in wanting a good life for animals destined to be killed in their prime for food. Animals on nonindustrial farms, he writes, are "simultaneously, an object to be killed and a subject to be nurtured."

He contends that the most ethical way to combat factory farming is to stop eating meat. The author has a strong point of view and *The Modern Savage* is not a data-driven report, but the book offers a thought-provoking critique of popular, often unquestioned, meat production methods. — *Beth Mole*

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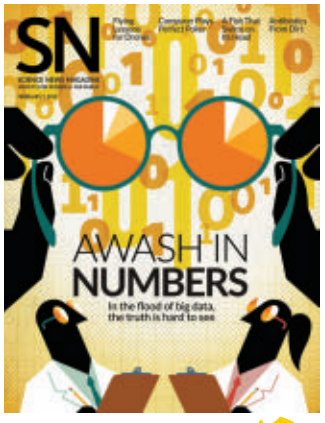

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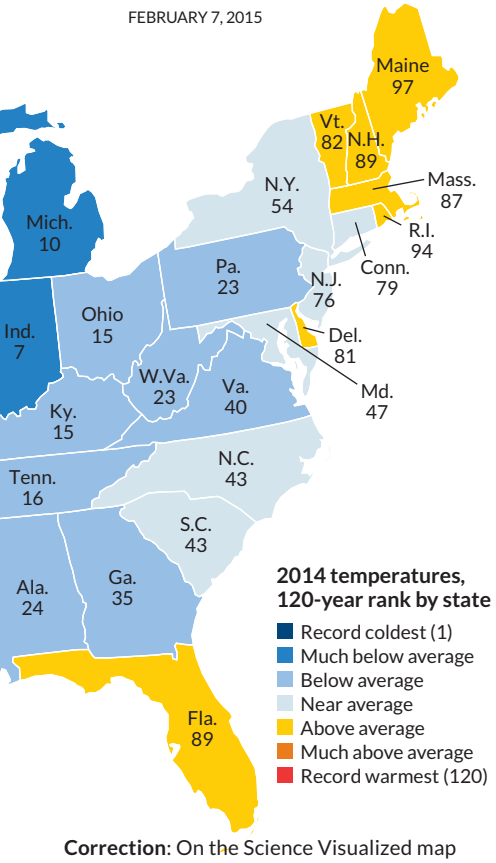

Correction: On the Science Visualized map (*SN: 2/7/15, p. 32*), the 120-year temperature rankings of Delaware, Florida and Rhode Island were correct, but the states should have been colored yellow, as above.

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Send in the drones

*Researchers are taking cues from bats, moths and swallows to develop fancy flight maneuvers for drones. In "High fliers" (*SN: 2/7/15, p. 18*), **Nsikan Akpan** described future unmanned vehicles that, like nature's best aerial acrobats, may dodge obstacles, navigate turbulent winds and land precisely on perches.*

Readers were wowed by the technical prowess expected in the next generation of drones. "Fascinating," commented **Jim LeSire**. "I didn't think they'd have the computer processing capability for doing this so soon. The mechanical aspects, yes, but not the 'brains.' Very impressive." On Twitter, **Will Spears** summed up the feelings of many readers: "The future looks exciting."

Others, though, expressed concerns about flooding the skies with human-made fliers. "Something I've not heard mentioned once is the potential ecological impact once drones begin to share many properties with wildlife, including size, shape and population density," wrote commenter **bruzote**. "Will falcons injure themselves on bird-sized drones? Also, how will a flock of birds behave when encountering a flock of drones?" After reading **Eva Emerson's** Editor's Note about the feature (*SN: 2/7/15, p. 2*), **Mayra Bloom** agreed that a more measured approach to describing the implications of new scientific endeavors such as drones was needed. "I encourage *SN's* superb editors to report not only the promise, but also the dangers, side effects and possible misuses of the science they represent and champion so ably."

The great exoplanet hunt

*Kepler's planet count continues to climb. An analysis of data from the space telescope adds new worlds to the catalog of suspected exoplanets, including a few that might host liquid water on their surfaces, as **Christopher Crockett** reported in "Kepler finds 554 potential planets" (*SN: 2/7/15, p. 9*).*

"I've read many articles that discuss how space researchers can detect planets revolving around their suns by seeing minute drops in the starlight as the planet or planets cross in front of their sun as seen from our telescopes," wrote **Steve Ostrom**. "Knowing that all planetary systems are not so perfectly aligned to our unique viewing angle, what would be the approximate percent of these star systems that give us such a great view of planet transits?"

Getting a good view depends on the size of the star and the length of the planet's orbit, **Crockett** says. Large stars provide a bigger target, and planets that huddle close to their stars can be seen from a wider variety of angles. The probability of seeing an Earth-like planet transit a sun-sized star, for example, is only about 0.5 percent. But that number jumps to nearly 10 percent when the planet's distance from its sun-sized star is one-tenth of Earth's distance from the sun. The reason Kepler has found so many planets — more than 1,000 confirmed and nearly 3,200 candidates — is that the telescope searched more than 150,000 stars.

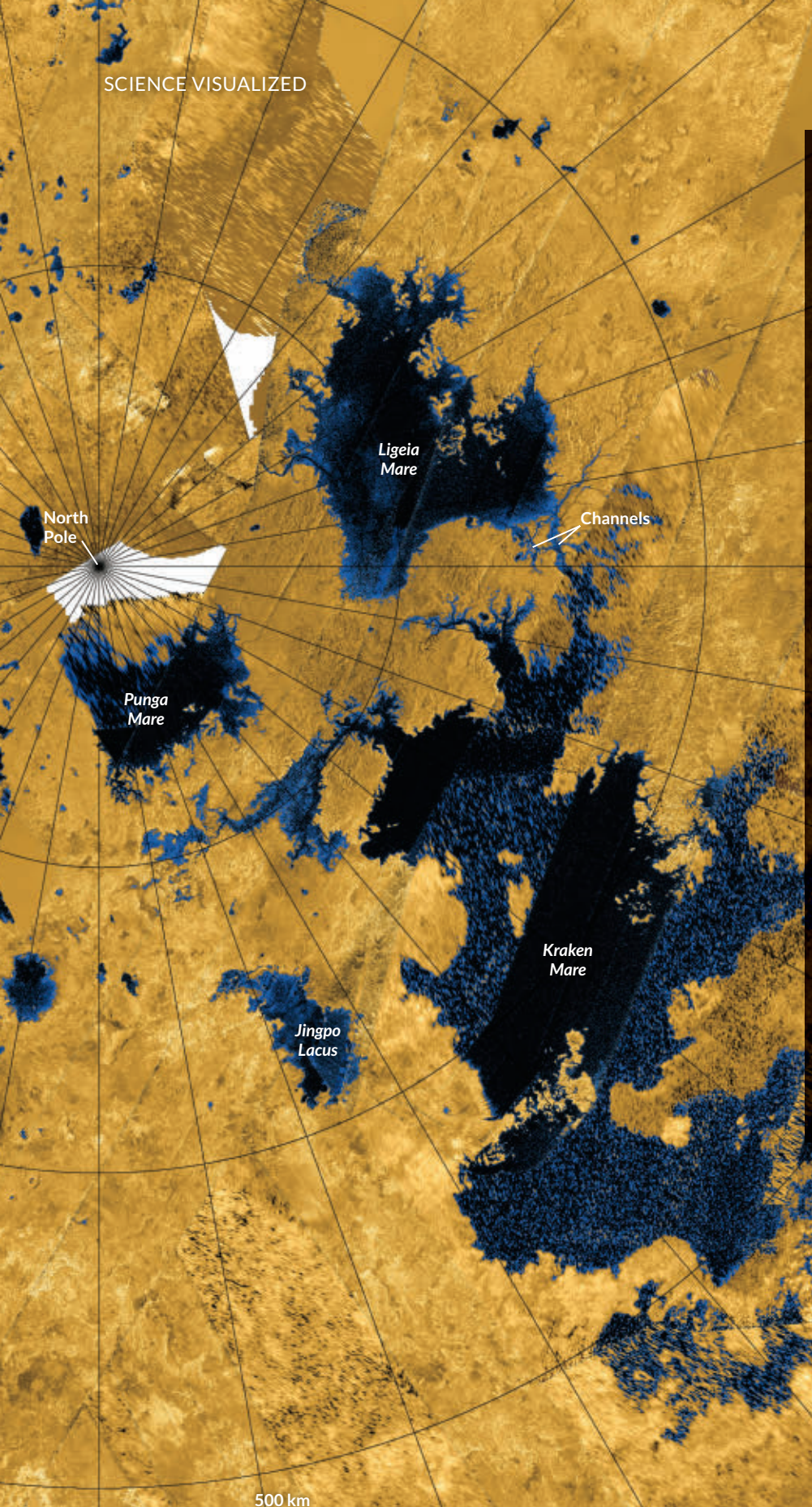
Playing the machine

*In "Computer algorithm masters poker" (*SN: 2/7/15, p. 14*), **Andrew Grant** introduced Cepheus, a program that's proved to be unbeatable at heads-up limit Texas Hold'em despite knowing nothing about its opponent's hand.*

"I just finished reading Brian Christian's *The Most Human Human*, and was therefore very interested in **Grant's** article," wrote **Dennis Kell**. "One difference between poker and games like checkers and chess is the ability to 'read' other players. The most successful poker players do not bluff or call bets randomly. They read other players' actions. It would seem to be a great advantage to a computer that its human opponent cannot read its eyes or actions. No need for sunglasses."

Missing credit

In "High fliers" (*SN: 2/7/15, p. 18*), the credit for the photo of a hawk moth hovering in front of LED lights was omitted on Page 20. Jonathan P. Dyhr should receive credit for the image.



Alien oceanography

Beneath the orange haze cloaking Titan, Saturn's largest moon, it's raining methane. While not much falls — a couple of meters every few centuries — it's enough to fill seas 200 meters deep in the moon's northern hemisphere (*SN: 12/13/14, p. 13*).

Despite having an average temperature of about –180° Celsius, Titan is the only world in the solar system other than Earth with liquid on its surface (*SN: 1/25/14, p. 14*). Researchers are starting to understand how the alien seas, mapped by the Cassini spacecraft, help drive a global process strikingly similar to Earth's hydrological cycle.

Two of Titan's seas probably serve as a conduit to shuttle methane from north to south, says Ralph Lorenz, a planetary scientist at the Johns Hopkins Applied Physics Laboratory in Laurel, Md. Ligeia Mare in the rainy north is like a pristine mountain lake. "This stuff is pure, clear methane," he says. Liquid from Ligeia then trickles south through channels to the much larger Kraken Mare, Lorenz reported in August in *Geophysical Research Letters*. There, the methane evaporates in the drier air, leaving behind high concentrations of ethane and propane.

Substitute water for methane and salt for ethane and these seas resemble two on Earth, Lorenz says, with the low-salinity Black Sea flowing into the saltier Mediterranean. — *Christopher Crockett*

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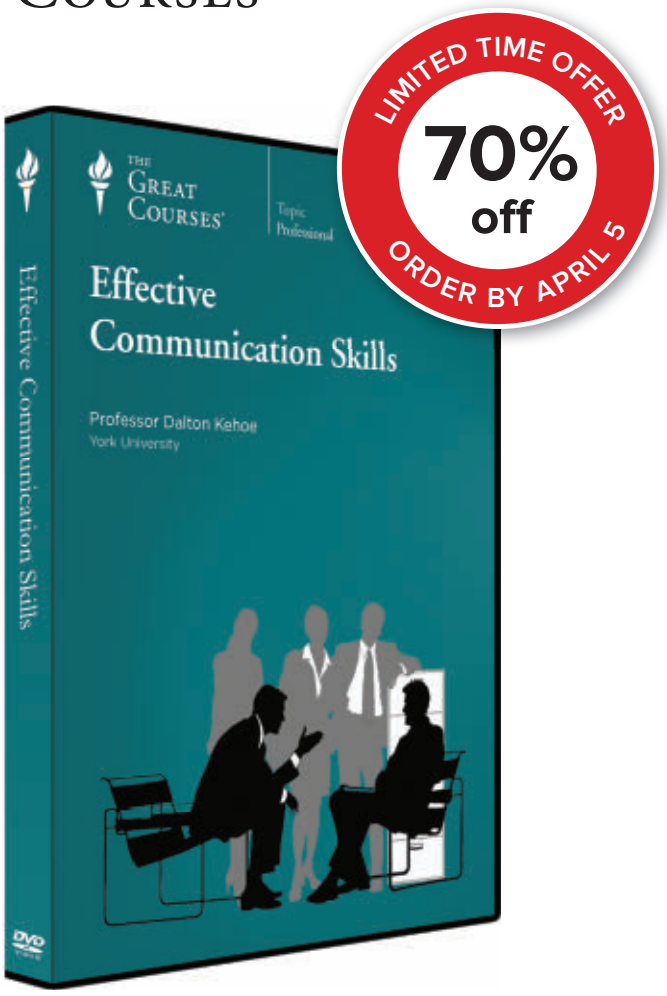

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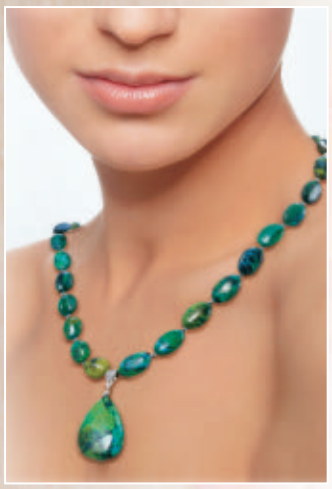

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