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ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ JANUARY 30, 2010

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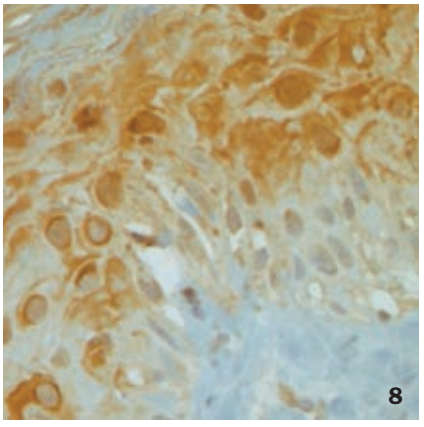

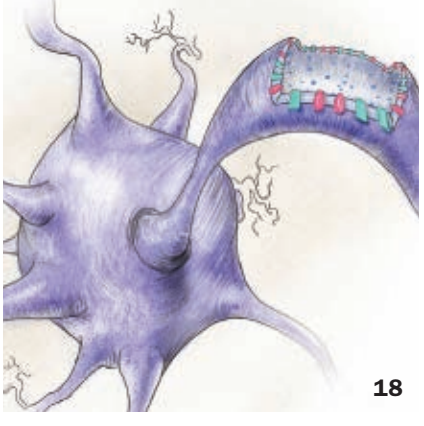

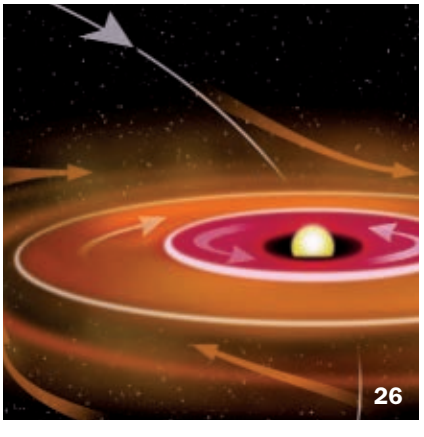

ScienceNews

In The News

Features

Departments

COVER A *Brachylophosaurus canadensis* skull gives way to a painting of the dino, standing in a 77-million-year-old wetland and bellowing a call to warn his herd of an ambush. *Painting by Julius T. Csotonyi*

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FROM THE EDITOR

To chemists, the universe is a vast cosmic test tube

Long before the evolution of life began on Earth, evolution of a different sort began to prepare the cosmos for life's arrival. In this case, the species that emerged and mutated and spawned offspring were not organisms, but molecules.

Once the universe gave birth to stars, nuclear reactions began to generate the elements that made complex chemistry possible. And then the stars exploded, seeding space with the raw materials necessary for natural chemical selection.

What happened after that was not precisely like the evolution of life, of course, as molecules don't exactly battle each other for survival. But some combinations of atoms are more stable than others. So when primordial atoms interacted under different conditions, only some of the resulting molecular species lived long enough to participate in further reactions. As nature continued to explore the vast space of chemical possibilities, simple molecules mated to produce more complicated species, opening the way to even more possible combinations, ultimately providing the cosmos with enough carbon-based molecular complexity to take chemistry to the next — the bio — level.

Today, scientists from various disciplines — astronomy, chemistry, biology — are busily studying the molecular populations occupying deep space, as *Science News* chemistry writer Rachel Ehrenberg reports in this issue (Page 26). Space has turned out to be a stellar laboratory for learning about the chemical history of the universe and how life's precursors may have arisen. It's also a new kind of chemistry lab for gaining insight into novel chemical processes, since on Earth it's very difficult to reproduce the expansive space, low pressures and long reaction times that are available in a cosmic setting.

Molecular species populating space today reflect the primordial processes of eons ago that made the universe an interesting place — and that make chemistry an interesting science. Those molecules may also help explain how it came to be that anyone was around to write about how interesting they are. In any event, cosmic chemical evolution deserves all the attention scientists are giving it as a worthy prequel to the earthly bio-evolution that ultimately led to science itself.

—Tom Siegfried, Editor in Chief

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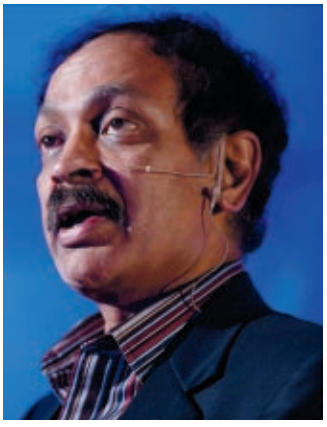

"All that's separating you from him, from the other person, is your skin. Remove the skin, you experience that person's touch in your mind. You've dissolved the barrier between you and other human beings. And this of course is the basis of much of Eastern philosophy, and that is, there's no real independent self aloof from other human beings, inspecting the world and inspecting other people. You're in fact connected. Not just via Facebook and the Internet.

You're actually quite literally connected by your neurons.... There's no real distinctiveness of your consciousness from somebody else's consciousness. And this is not mumbo jumbo philosophy, it emerges from our understanding of basic neuroscience. **—UNIVERSITY OF CALIFORNIA, SAN DIEGO NEUROLOGIST V.S. RAMACHANDRAN IN A TALK ON MIRROR NEURONS AND "EMPATHY NEURONS" POSTED IN JANUARY AT WWW.TED.COM**

Science Past | FROM THE ISSUE OF JANUARY 30, 1960

SAFE SEASONINGS NAMED — Some 150 seasonings and flavorings — ranging from the familiar cinnamon to exotic "ylang-ylang" — have been put on the safe list, the Food and Drug Administration has announced. Manufacturers who use these flavors in their food products need not furnish further proof of their safety. The list includes cloves, nutmeg, thyme, vanilla ... and balsam of Peru.... Seven flavoring substances are on the "wait and see" list, however. Safe usage for these is not "sufficiently well established among qualified experts to permit a formal determination by FDA that they are generally recognized as safe." They include quinine, red and yellow cinchona barks, two forms of orris root ... wintergreen and methyl salicylate.

Science Future

February 20–21
Free science discussion sessions and demos are open to the public at the AAAS annual meeting in San Diego. See www.aaas.org/meetings/2010

February 24–26
The International Stroke Conference 2010 is held in San Antonio. See strokeconference.org

March 31
New nomination deadline for the 2010 National Medal of Science. Get forms at www.nsf.gov/od/nms/medal.jsp

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EARTH
A warming climate has central Europe buzzing with extra insect generations, as in the common blue butterfly (shown). See "Warming has already boosted insect breeding."

MATH TREK
Mathematicians harness computer powers to identify fake works of art. Read "Teaching a computer to spot a bogus Bruegel."

SCIENCE & THE PUBLIC BLOG
Never mind the venom, a tarantula can prove an eyesore. Read "Pet tarantulas can pose a hairy threat."

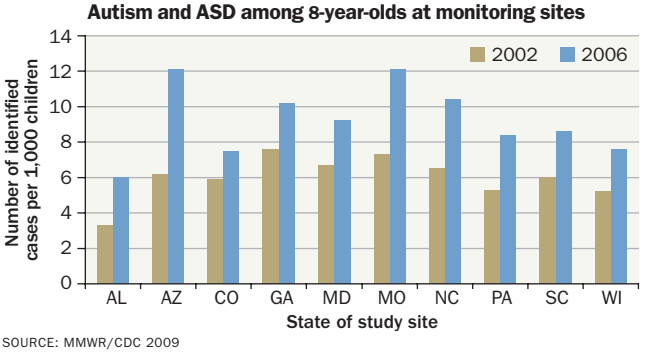
ATOM & COSMOS
A new study on the origin of comets may also help solve a cosmic riddle. See "Comets don't all start out on the fringe."

Introducing...

By analyzing a skeleton and the surrounding tomb (shown) found in western Honduras, researchers have identified what could be the remains of the first king of the ancient Mayan city of Copán. Hieroglyphics had suggested the ruler was named K'inich Yax K'uk' Mo', or KYKM. Bone analyses led the researchers to conclude that the skeleton could belong to KYKM, they report in an upcoming *Journal of Anthropological Archaeology*. But KYKM wasn't native to Copán. Isotopic evidence now shows that he likely grew up northwest of the city and became king around 430 during Mayan colonization efforts.

Science Stats | AUTISM IN AMERICA

Autism and autism-spectrum disorder, or ASD, cases rose between 2002 and 2006. Estimates now are that 1 in 110 U.S. kids has autism or ASD.

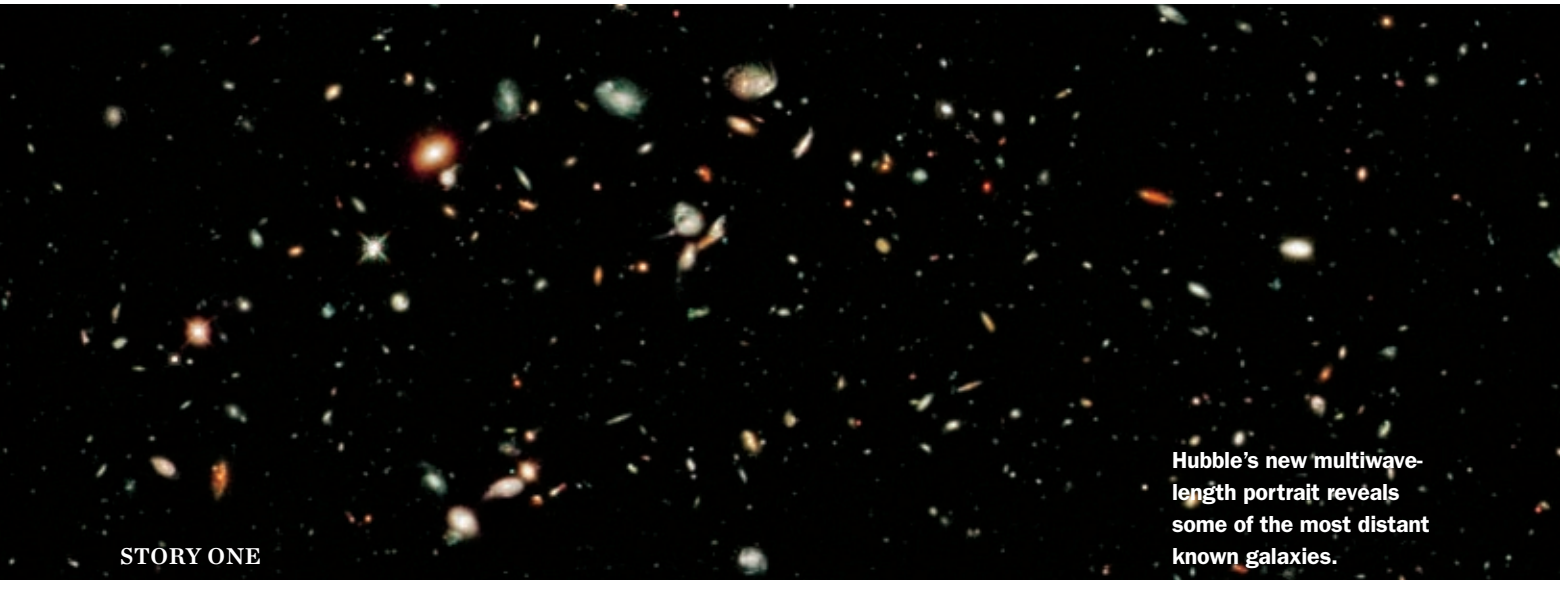


SOURCE: MMWR/CDC 2009

CLOCKWISE FROM TOP LEFT: TED/JAMES DUNCAN DAVIDSON; F. ALTERMATT; COURTESY OF THE EARLY COPÁN ACROPOLIS PROGRAM/U. OF PENN. MUSEUM, INSTITUTO HONDUREÑO DE ANTROPOLOGÍA E HISTORIA

“Our whole notion of ourselves as a species is slightly misconceived.” — ROBERT GIFFORD, PAGE 10

In the News



Hubble’s new multiwavelength portrait reveals some of the most distant known galaxies.

NASA; ESA; R. WINDHORST, S. COHEN, M. MECHTLEY, M. RUTKOWSKI/ARIZONA STATE UNIV.; R. O’CONNELL/UVA; P. MCCARTHY/CARNEGIE OBSERVATORIES; N. HATHI/UC RIVERSIDE; R. RYAN/UC DAVIS; H. YAN/OHIO STATE UNIV.; A. KOEKEMOER/STSCI

STORY ONE

Galaxies may be most distant yet

Potential Hubble findings push limits of current technology

By Ron Cowen

They’ve gone as far as they can go. By pushing the refurbished Hubble Space Telescope to its very limits as a cosmic time machine, astronomers have identified three galaxies that may hail from an era only about 450 million years after the Big Bang. If that preliminary determination is correct, then the faint galaxies are the most distant starlit bodies known, each lying some 13.2 billion light-years from Earth.

Such galaxies bring astronomers about 150 million years closer to cosmic dawn, the time when the first galaxies and stars switched on. Finding more galaxies of this type may help researchers better understand how bodies in the early universe formed and whether galaxies or the supermassive black holes housed within them evolved first.

The new findings are at the very edge of what current technology can accomplish, comments Richard Ellis of Caltech, who was not part of the new study. No telescope now in existence can spot galaxies any further back in time. Such discoveries will have to wait until the launch of Hubble’s successor, the infrared James Webb Space Telescope, in 2014.

“This is uncharted territory,” says Garth Illingworth of the University of California, Santa Cruz, a coleader of the study. Illingworth and Rychard Bouwens, also of UC Santa Cruz, along with several collaborators, posted their findings online December 23 at arXiv.org.

Because light from remote galaxies must travel for billions of years to reach Earth, the radiation emitted by the bodies reveals how they appeared some 13.2 billion years ago.

The stars within those galaxies would have formed even earlier, probably about 13.4 billion years ago. The radiation from such early galaxies played a crucial role, theorists believe, in reionizing the universe. Reionization breaks apart hydrogen atoms, which absorb light, into electrons and protons. Once the atoms are broken apart, light from the first generation of stars can stream freely into space.

Because the galaxies found with Hubble are seen at only one wavelength, the astronomers caution, it’s not certain that the bodies are extremely distant — they could just be red and faint. “We certainly don’t have smoking gun evidence,” says Bouwens. “We just have tantalizing evidence that suggests we may be identifying a few [extremely distant] galaxies.”

The Bouwens-Illingworth team, like several others, went hunting for distant galaxies using Hubble’s newly installed Wide Field Camera 3, which in August took

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the deepest infrared image of the universe ever recorded. Another Hubble camera had examined the same patch of sky, the Hubble Ultra Deep Field, five years earlier in visible light. This well-publicized image revealed many faint, faraway galaxies, but not the most remote galaxies, which can be seen only in infrared.

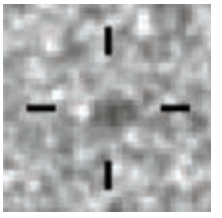
Ultraviolet and visible light emitted by the youthful stars in the earliest, most distant galaxies is shifted to much longer wavelengths — the infrared part of the spectrum — by the expansion of the universe. The more remote the galaxy, the greater the redshift.

In September, two teams, including Bouwens-Illingworth's, reported finding galaxies with redshift values of 7 to 8, corresponding to an era about 700 million years after the Big Bang. Since then, five teams have posted some 15 papers online about those galaxies, which have been observed at two sets of wavelengths and so are on surer footing.

On January 5 in Washington, D.C., at the winter meeting of the American Astronomical Society, Illingworth reported that these galaxies, which are teeming with newborn stars, are about 5 percent the size and 1 percent the mass of the Milky Way, according to observations with the Spitzer Space Telescope. These are the seed galaxies that merged to form giant galaxies like the Milky Way, he said.

In their paper at arXiv.org, the researchers estimate that the three even more distant galaxies imaged by the Wide Field Camera 3 have a redshift of about 10, which if confirmed would be the largest redshift ever measured. Another team, led by Rogier Windhorst of Arizona State University in Tempe, reported on arXiv.org finding a separate group of 20 galaxies at that redshift using the same data from the refurbished Hubble.

Illingworth and Bouwens note that because most of the candidate distant galaxies that were identified by the Windhorst team lie near known, bright galaxies, the team may have been confused by stray light from these bright galaxies.



This galaxy, recorded with Hubble's Wide Field Camera 3, may be one of the most distant known, with a redshift of 10.

"Bouwens and company appear to have done a more careful job than Windhorst's team," Ellis comments.

Ellis and other astronomers have said it would be surprising if all 20 galaxies found by Windhorst and his collaborators are from the same early era, since the Ultra Deep Field encompasses a narrow strip of sky. Such a finding would indicate that the early universe had a surprisingly high density of these galaxies.

Windhorst now says that a further analysis indicates that perhaps 10 of his team's galaxies may not turn out to be so very distant after all.

Although the race is on to find more-convincing examples of distant galaxies, it's likely that none of the candidates at redshift 10 can be confirmed until the launch the James Webb Space Telescope, astronomers agree. ■

Back Story | SEEING IN RED

Distant galaxies appear to be receding from Earth because of the universe's expansion, which shifts their light toward the red end of the spectrum. Technically, a galaxy's redshift, or z, is a measure of its velocity away from Earth, but astronomers also use it as a gauge of the universe's age at the time the light was emitted. With data on the age of the universe and expansion rate, a measured redshift can be translated into a distance in light-years that indicates how long it took the galaxy's light to travel to Earth. The table gives travel times for various redshifts based on an age for the universe of 13.7 billion years and an expansion rate of 71 kilometers per second per megaparsec. The images show cosmic bodies with various redshifts.

z	Age of universe	Light travel time to Earth
1	5.9 billion years	7.7 billion years
2	3.3 billion years	10.3 billion years
4	1.6 billion years	12.1 billion years
6	950 million years	12.7 billion years
8	650 million years	13 billion years
10	480 million years	13.2 billion years

SOURCE: NED WRIGHT'S COSMOLOGY CALCULATOR, WWW.ASTRO.UCLA.EDU/~WRIGHT/COSMOCALC.HTML

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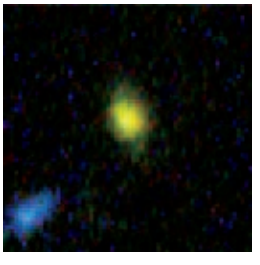
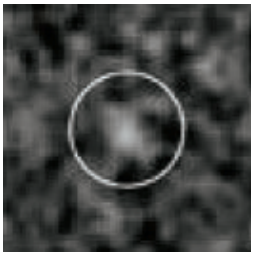


4.0 Galaxy from the Hubble Ultra Deep Field

5.42 Galaxy from the Hubble Ultra Deep Field

6.5 Galaxy HUDF-JD2 from the Hubble Ultra Deep Field



7.4 Candidate galaxy described in 2006

TOP: NASA, ESA, G. ILLINGWORTH, R. BOUWENS, THE HUDF09 TEAM; BACK STORY, FROM LEFT: NASA, J. BLAKESLEE/JHU; NEXT TWO: NASA, ESA, N. PIRZKAL/STSCI; NASA, ESA, B. MOBASHER/STSCI; NASA, ESA, R. BOUWENS, G. ILLINGWORTH/UC SANTA CRUZ

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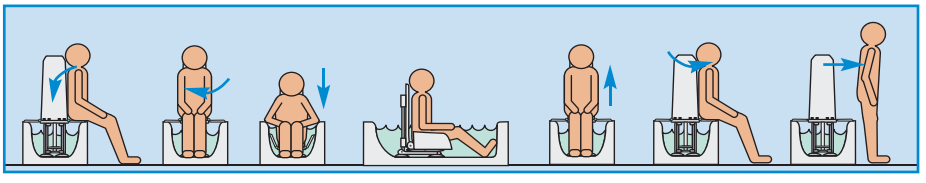

Body & Brain

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Gunshot victims have need for speed

Delay for spine stabilization doubles death risk, study finds

By Nathan Seppa

In a study that runs counter to emergency-care protocols in some regions of the United States, researchers have found that gunshot patients who undergo spine stabilization before being transported to the hospital are twice as likely to die as those who are taken directly.

The problem appears to be the delay, researchers report in the January *Journal of Trauma*. To stabilize the spine, paramedics wrap a cervical collar around a patient's neck and strap the individual to a long board to keep the vertebrae from shifting during transport. Although these measures immobilize the spine, the patient loses precious minutes.

"Some injuries are very time sensitive," says study coauthor Elliott Haut, a trauma surgeon at the Johns Hopkins Hospital in Baltimore, which averages one gunshot patient per day. "Sometimes, if you get here in 10 minutes we can save your life, but in 20 minutes we can't," he says. Spine immobilization delays a trip to the hospital by two or three minutes on average, but can take more than five minutes, previous research has shown.

Although spine stabilization has proved its worth for car-crash patients, no studies had established whether it helps patients with gunshot or knife wounds to the neck or torso, where such wounds might include spine damage. So Haut and colleagues scanned a nationwide database of roughly 45,000 patients treated for these wounds. About 15 percent of patients who received spine immobilization died in the hospital, compared with 7 percent of those not immobilized. When the researchers accounted for differences in wound severity, gender, race and age, the difference remained twofold.

A closer look at the data revealed that spine immobilization didn't affect death rates in patients with knife wounds. The gunshot wound patients most affected by immobilization were those with low blood pressure.

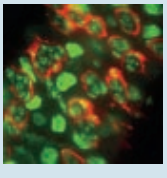
Patients with partial spine damage from trauma harbor the greatest risk of vertebrae movement during transport and are most likely to benefit from spine stabilization. But those cases are rare among gunshot victims, says neurosurgeon Craig H. Rabb of the University of Oklahoma Health Sciences Center in Oklahoma City. The greater death rate among people in this study who got spine immobilization underscores that delay is the enemy, he says. "This provides powerful evidence that [paramedics and EMTs] should feel reassured that they're unlikely to cause problems" by forgoing immobilization for gunshot patients, Rabb says.

The protocols that govern ambulance crews' emergency medical care vary by locality. Haut says the new findings should be factored into these guidelines. ■

NEWS BRIEFS

Fruit fly bodies bank stem cells

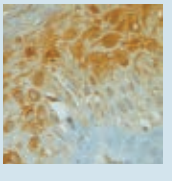
Stem cells lead sheltered lives. A new study of fruit flies shows how stem cells create safe niches (shown in red, left) that hold a reserve of undifferentiated stem cells to draw on later to create and replenish organs or repair wounds. The findings may have implications for cancer and regenerative medicine.



When a stem cell in the fruit fly gut divides, it creates a daughter cell that wraps itself around its mother and siblings and prevents them from turning into specialized tissues, researchers report online January 7 in *Science*. The stem cell, a precursor to an intestinal cell, sends a signal to one of its daughters. The daughter cell then becomes a peripheral cell, which acts "like an octopus covering other cells with its tentacles," says Columbia University's Benjamin Ohlstein, who led the research. During the flies' larval stage, the peripheral cells protect their stem cell siblings from becoming digestive cells prematurely. As the larva metamorphoses into an adult, the niche breaks down and most of the cells begin to form the gut. A few remain stem cells, standing at the ready to replace cells that are damaged or have sloughed off. —*Tina Hesman Saey*

Protein signals cause of rash

A new blood test can reveal whether a skin rash signals a high-risk complication or just a nuisance in people who have undergone a bone marrow transplant, James Ferrara of the University of Michigan and colleagues report in the Jan. 6 *Science Translational Medicine*. Some transplant patients develop graft-versus-host disease, in which the newly grafted bone marrow cells attack tissues in the body. Now researchers show that transplant patients with rashes caused by GVHD have elevated levels of a protein called elafin (orange in skin cells, below) in their blood and skin. Scientists also tracked the progress of 159 patients who had a skin rash from GVHD. Those with lower blood elafin levels when GVHD was diagnosed were nearly twice as likely to be alive five years after transplant as those with higher levels. Elafin levels might be a tip-off for the potential severity of GVHD, says Harvard's Joseph Antin. —*Nathan Seppa*



FROM LEFT: COURTESY OF *SCIENCE*/AAAS; J. FERRARA/UNIV. OF MICHIGAN

Earth

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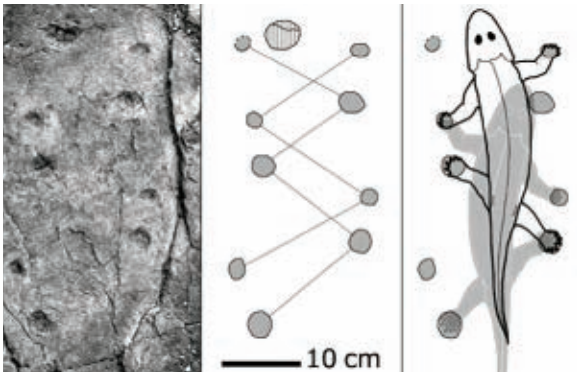
Fossil footprints could push back origin of first four-limbed animals

Tracks challenge thinking on age of sea-to-land transition

By Sid Perkins



Trackways in ancient rocks, left, push back evidence for tetrapods by some 18 million years. The footprints, center, suggest a walking style shown at right.

Fossilized footprints found in an abandoned quarry in Poland hint that four-limbed creatures called tetrapods evolved much earlier and in a radically different environment than previously thought.

The footprints — many individual impressions, as well as some arranged in sets called trackways — are preserved in 395-million-year-old rocks in the Holy Cross Mountains of southeastern Poland, paleontologist Per E. Ahlberg and colleagues report in the Jan. 7 *Nature*. That age substantially predates previous estimates for when animals left the sea to live on land.

Evidence suggests that the carbonate rocks were laid down as sediments in the intertidal areas of a tropical shoreline, possibly in a lagoon, says Ahlberg, of Uppsala University in Sweden.

The presence of footprints in rocks of this age is surprising: The tracks date to 18 million years earlier than body fossils of tetrapods. And the footprints are about 10 million years older than body fossils of creatures such as *Tiktaalik* and *Panderichthys* (*SN: 6/17/06, p. 379*), believed to represent the transition from lobe-finned fish to fully land-adapted creatures.

The findings "force a radical reassessment of the timing, ecology and environmental setting of the fish-tetrapod transition," the team contends. Previous studies have suggested that the first tetrapods hauled up on lakeshores or in freshwater deltas, but these trackways hint the water-to-land transition could have happened in a shallow marine setting.

In some areas of the quarry, the fossilized footprints are so common that they fall on top of and partially obliterate one another, forming what Ahlberg and his colleagues call a "densely trampled surface." Also peppering the surface are small craters made by falling raindrops — a sign that the ancient sediments were exposed to the air at least part of the day, the researchers say.

The arrangement of footprints in one trackway — including stride length and relative spacing, as well as the absence of an impression from a sagging tail — suggests that a tetrapod between 40 and 50 centimeters long left the tracks. Individual footprints in this set didn't have sharply defined edges, possibly because the creature traipsed through squishy sediment in shallow water.

Other footprints at the site, however, were made by a larger, similar animal and include signs of toes. Most of those prints are about 15 centimeters wide and were probably made by a tetrapod about 2.5 meters long, the team estimates.

Because the rocks don't contain any body fossils, it's difficult to interpret what type of animal made the tracks, says Jennifer A. Clack of the University of Cambridge in England. "If the isolated footprints are what they seem to be, the creature was relatively enormous," she says. "If fossils of the creature that made these tracks are ever found, they could well upset the apple cart of what people thought about tetrapod evolution."

Constantly changing water levels make intertidal areas dynamic environments, Clack says. In such a setting — where substantial quantities of food might have been stranded in shallow water when tides rolled out — evolution would have favored adaptable predators, she contends.

The newly described footprints and trackways "are a very exciting find," says Anthony J. Martin of Emory University in Atlanta. "The combination of trampled surfaces, multiple trackways with tetrapodal gait patterns [and] distinct individual tracks with distinct digit impressions ... makes a very persuasive argument that these structures are tetrapod trace fossils."

Other scientists, however, aren't convinced that tetrapods left the footprints. "These are interesting trace fossils," says Ted Daeschler of the Academy of Natural Sciences in Philadelphia. He notes, however, that trace fossils are notoriously difficult to interpret with confidence. Also, the arrangement of individual footprints in the trackways reflects a style of walking not seen again in the fossil record until 50 million years later, he says. (No *Tiktaalik* or *Panderichthys* trackways have been discovered.) "All together, the new evidence isn't strong enough to make me discard the current, well-supported ideas about the timing of tetrapod evolution," he says.

Many of the newly described footprints are indistinct and possibly not even made by tetrapods, but finding anything from that far back in time is still exciting, comments Robert L. Carroll of McGill University's Redpath Museum in Montreal. The indistinct tracks could be impressions made in soft sediments by lobe-finned fish, he notes. ■

Genes & Cells

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Devilish cells get blame for cancer

Genetic studies find culprits in Tasmanian tumor deaths

By Tina Hesman Saey

Scientists have discovered the identity of a contagious cancer that kills Tasmanian devils. The cancer, devil facial tumor disease, stems from cells that normally insulate nerve fibers, a new study shows.

Genetic analysis of tumors taken from infected devils in different parts of Tasmania reveals that these insulating cells, known as Schwann cells, became cancerous in a single devil and have since passed to other devils, an international team reports in the Jan. 1 *Science*.

Scientists suspected that a virus might cause the tumors, but the study confirms that the cancer cells themselves are transmitted from devil to devil.

Knowing the origin of the contagious tumors could help conservationists diagnose the disease more accurately and may lead to a vaccine that would target tumor proteins, says Katherine Belov, a geneticist at the University of Sydney who was not involved with the project.

A contagious cancer has wiped out some 70 percent of the wild Tasmanian devil population (healthy one shown).

A vaccine against the facial tumor disease, "while now pie in the sky, in 10 years might not be," says Gregory Hannon of Cold Spring Harbor Laboratory in New York. "Ten years might be enough time" to save the devils from extinction, he says.

About 70 percent of the wild Tasmanian devil population has disappeared as a result of the disease. If the current rate of decline continues, devils could become extinct in 30 to 50 years, says Elizabeth Murchison. A native of Tasmania who grew up seeing devils in the wild, Murchison led the project while working in Hannon's lab but is now at the Wellcome Trust Sanger Institute in Hinxton, England. "I didn't want to sit back and let the devils disappear," she says.

Genetic data about Tasmanian devils have been lacking, Belov says. An effort to decode the species' genome is underway but is not yet complete. The new study provides the largest genetic data set collected to date for the species.

Murchison and her team analyzed patterns of gene and microRNA activity in facial tumors and in healthy tissue. All 25 tumors the team analyzed were genetically identical, indicating that the tumors came from a single source — most likely a devil that lived about 20 years ago.

Human genome hosts bornavirus

RNA virus hitchhiker invaded DNA at least 40 million years ago

By Tina Hesman Saey

People may not be quite the humans they think they are. Or so suggests new research showing that the human genome is part bornavirus.

Bornaviruses, a group of RNA viruses that cause disease in horses and sheep, first inserted their genetic material into ancestral human DNA at least 40 million years ago, the study shows. The findings, published January 7 in *Nature*, provide the first evidence that RNA viruses other than retroviruses (such as HIV) can stably integrate genes into host DNA. The new work may help reveal more about the evolution of RNA viruses.

"Our whole notion of ourselves as a species is slightly misconceived," says Robert Gifford, a paleovirologist at the Aaron Diamond AIDS Research Center in New York City. Human DNA includes genetic contributions from bacteria and other organisms, and humans have even come to rely on some of these genes for basic functions like fighting infections.

Now Keizo Tomonaga of Osaka University in Japan and colleagues have found copies of the bornavirus N gene inserted in at least four locations in the human genome. These genes, considered molecular fossils of an ancient bornavirus, have also turned up in searches of a variety of other mammalian genomes.

"Clearly they provide a fossil record of bornavirus that was previously only available for retroviruses," says study coauthor John Coffin, a virologist at Tufts University School of Medicine in Boston. "It tells us that virus evolution doesn't proceed the way many people have viewed it."

Scientists have long had direct evidence of retroviruses' ancient origins: Molecular fossils of those viruses persist in the genomes of species infected long ago.

But bornavirus and other RNA "viruses all look like they are relatively young, which doesn't make any sense," says Michael Emerman, a virologist at the Fred Hutchinson Cancer Research Center in Seattle.

Many virologists had suspected that RNA viruses like bornavirus were much older than estimates based on mutation rates. The high mutation rates in RNA viruses suggest that their molecular clocks are ticking faster than in other viruses.

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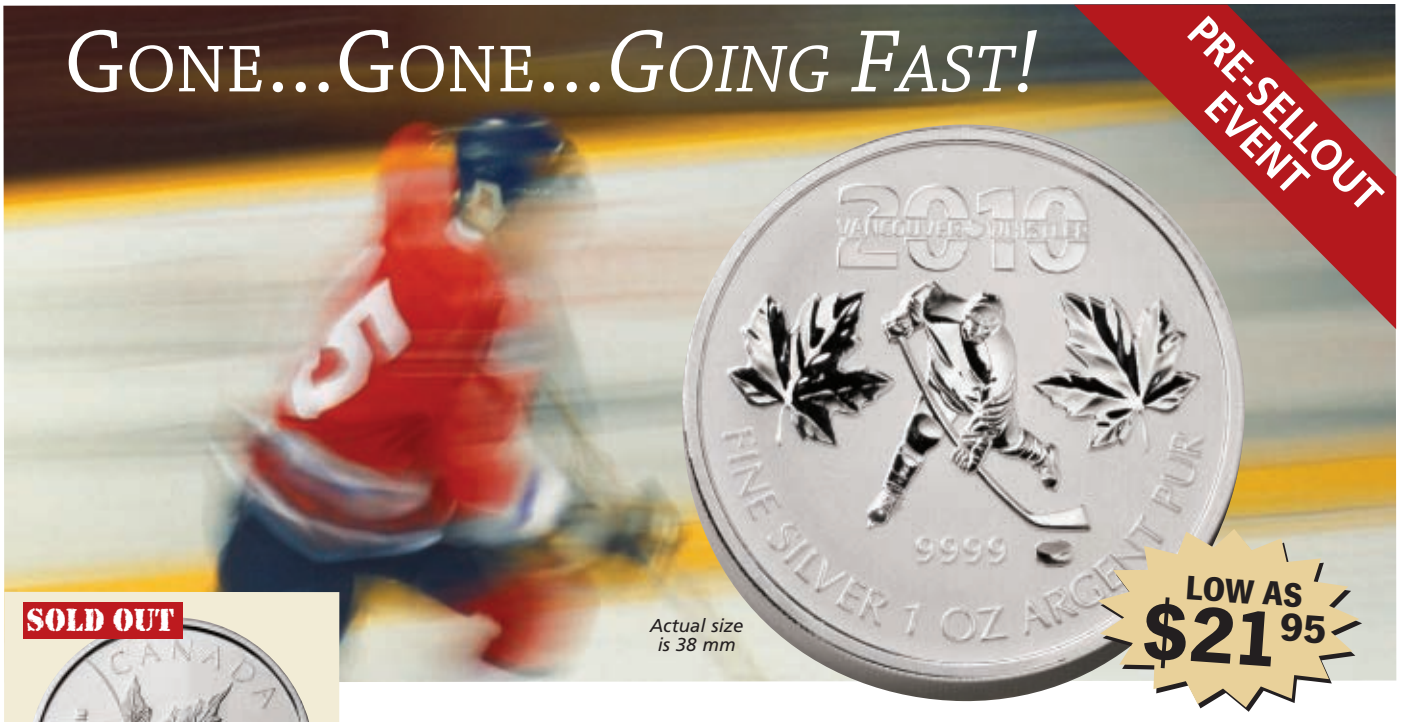

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New planet-hunter captures quarry

Kepler mission spots five extrasolar orbs in first six weeks

By Ron Cowen

NASA's planet-hunting Kepler mission is off to a precocious start. The first six weeks of observations recorded by the spacefaring telescope, combined with follow-up studies from the ground, have revealed five previously unknown extrasolar planets — one body roughly the size of Neptune and four low-density versions of Jupiter. All reside within roasting distance of their parent stars.

The findings appear to reinforce hints from ground-based telescopes that stars have relatively few close-in planets with a mass between that of Saturn and Neptune, says Dimitar Sasselov of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass.

Lead mission scientist William Borucki of NASA Ames Research Center in Moffett Field, Calif., and colleagues reported the findings on January 4, and a paper describing the results appeared online January 7 in *Science*.

Astronomers say that the early results bode well for achieving Kepler's main goal: finding Earthlike planets in or near the habitable zones of sunlike stars.

Kepler, launched in March 2009 and expected to last 3½ years, detects planets by recording tiny decreases in starlight when one transits, or passes across the face of its parent star. Kepler "has already established that Earth-size transiting planets can be found," says theorist Sara Seager of MIT, a member of the discovery team. "We are salivating over the upcoming data and Kepler discoveries."

> "We are salivating over the upcoming data and Kepler discoveries."
>
> SARA SEAGER, MIT

The least-massive planet found by Kepler during its early observations, dubbed Kepler-4b has a radius and density comparable to that of both Neptune and GJ 436b, a Neptune-like transiting planet observed by the European COROT satellite in 2007.

Even though Kepler-4b is blasted with 800,000 times more radiation from its star than is Neptune or GJ 436b, all three orbs are similar in size. That suggests that Kepler-4b has a denser composition, with either a higher ratio of rock to water or a lower ratio of hydrogen to helium gas, Borucki and colleagues noted.

None of the five planets Kepler discovered would be habitable. All have temperatures at least as high as in molten lava, and two, Kepler-5b and Kepler-8b, reside so close to their parent stars that their average temperature is high enough to melt iron.

The four hot, Jupiter-like planets have densities lower than predicted for giant, gaseous planets. One, Kepler-7b, has one of the lowest densities — 0.17 grams per cubic centimeter — of any known extrasolar planet. That's the same density as Styrofoam, Borucki noted during his talk. (By comparison, Jupiter's average density is 1.33 grams per cubic centimeter, slightly higher than that of water, but Jupiter lies much farther from the sun than Kepler-7b does from its star.)

Borucki also noted that Kepler has identified another 100 planetary candidates. His team is now analyzing those to determine which ones, if any, might be actual extrasolar planets.

NASA, JPL-CALTECH, UCLA, WISE TEAM

WISE sees its first stars

NASA's WISE eyes are open. Launched on December 14, the Wide-field Infrared Survey Explorer is poised to begin the most thorough survey yet of the infrared universe. The telescope's first image, a field of about 3,000 stars in the constellation Carina (colorized image shown), was released January 6. Orbiting 525 kilometers above Earth, WISE will snap a picture every 11 seconds during its nine-month mission, scanning the entire sky one and a half times in search of asteroids, brown dwarfs and distant galaxies. The first image mostly lacks these features; that swath of sky was chosen for safety to avoid objects that could damage the telescope's detectors. But the image is a good sign, said mission scientist David Leisawitz of NASA's Goddard Space Flight Center in Greenbelt, Md. It shows that the telescope is in focus and picking up details in infrared wavelengths. Preliminary WISE images will be released in April 2011; a final atlas is to come in March 2012. —*Lisa Grossman*

1 million Pixels in each of WISE's four detector arrays

8 kelvins Temperature of WISE's coldest detectors

75 hundred Rough number of images WISE takes per day

Black holes seen dancing in pairs

Merging galaxies play host to astrophysical pas de deux

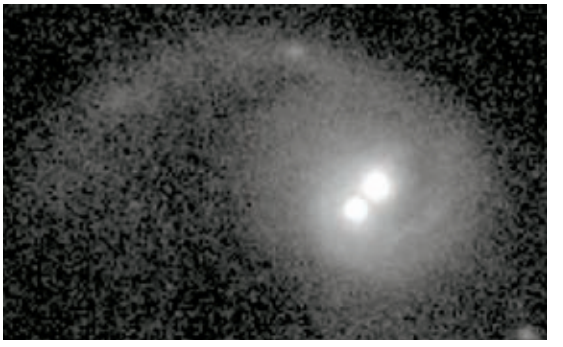
By Lisa Grossman

The universe may be one big dance party for black holes. New observations from the W.M. Keck Observatory in Hawaii and the Hubble Space Telescope reveal 33 merged galaxies in which pairs of supermassive black holes are "waltzing" around the galactic centers.

"Our result shows that such waltzing black holes are much more common than we previously knew," reported Julie Comerford of the University of California, Berkeley on January 4. "We expect the universe to be littered with these.... But until recently, only a few had ever been found."

Finding pairs of black holes moving in this way can help scientists estimate how often galaxy mergers occur in the universe.

Observations have shown that nearly every galaxy has a supermassive black hole — a black hole with a mass from a million to a few billion times that of the sun — at its center and that galaxies often collide and merge to create larger galaxies. Astronomers have expected to find many galaxies in the midst of merging by focusing on the two supermassive black holes, which should be orbiting each other in the middle. But so far, the dance floor has been pretty much empty.



A Hubble telescope image of the galaxy COSMOS J100043.15+020637.2 shows two nuclei, possibly black holes paired by a merger of two smaller galaxies.

Using new techniques, Comerford and her colleagues have now found 33 galaxies with dual supermassive black holes. By determining whether each black hole is moving toward or away from Earth, one technique revealed 32 black hole pairs locked in step in the DEEP2 Galaxy Redshift Survey, which was conducted at the Keck II Telescope on Hawaii's Mauna Kea.

The final black hole duo was found serendipitously in a Hubble image of the galaxy COSMOS J100043.15+020637.2. That galaxy sports a tidal tail of stars, gas and dust, a sign of a recent galaxy merger. The galaxy also has two bright nuclei, each of which could be a supermassive black hole surrounded by glowing dust and gas.

Where there's smoke, supernovas

Gamma-ray burst may have illuminated ancient stardust

By Ron Cowen

Astronomers may have detected "smoke" signals generated by supernovas that blew up when the universe was less than 1.4 billion years old. If correct, the find would be one of the earliest known signs of supernova-produced dust in the universe, and the earliest dust detected thanks to a gamma-ray burst.

The supernovas are too faint and too far away to be seen directly. But the smoke, or stardust, they produced when they erupted now appears to have been revealed by the brilliant afterglow of a much more powerful type of eruption, a gamma-ray burst.

The new finding "is exciting because gamma-ray bursts are showing themselves as a unique probe of the early universe that really hadn't been considered," Joshua Bloom of the University of California, Berkeley reported on January 4. "We can now measure how matter in the [young] universe converts from stars into stardust," the raw material for the next generation of stars, he added. Bloom, Daniel Perley of UC Berkeley and colleagues also posted the findings online.

Stardust is known to absorb visible and ultraviolet light and to re-emit light at longer, infrared wavelengths. Gamma-ray bursts are mammoth explosions featuring jets of high-speed particles that spawn gamma rays. Bursts lasting more than a second or two are believed to mark the catastrophic collapse of a massive star into a black hole.

When the astronomers examined visible and infrared afterglow of a gamma-ray burst discovered in 2007, dubbed GRB 071025, they found telltale light absorptions indicating the presence of dust. Bloom said that the team tried several models to explain the properties of the afterglow light from the gamma-ray burst, but only supernova dust fit the bill.

In nearby reaches of the universe, including the Milky Way, most dust is produced by mature, low-mass stars. But at much earlier times, such as when GRB 071025 exploded (about a billion years after the Big Bang), low-mass stars were not yet common. Instead, Bloom noted, supernovas were the dominant — and perhaps only — source of dust.

The team suggests that light from this gamma-ray burst passed through an unusually dusty part of its galaxy, where a series of supernovas had enriched the surrounding space with dust grains.

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Humans

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Raft out of Africa: early hominids as ancient mariners

Hand axes excavated on Crete suggest sea crossings

By Bruce Bower

Human ancestors that left Africa hundreds of thousands of years ago to see the rest of the world were no landlubbers. Stone hand axes unearthed on the Mediterranean island of Crete indicate that an ancient *Homo* species — perhaps *Homo erectus* — had used rafts or other seagoing vessels to cross from northern Africa to Europe via at least some of the larger islands in between, said archaeologist Thomas Strasser of Providence College in Rhode Island.

Several hundred double-edged cutting implements discovered at nine sites in southwestern Crete date to at least 130,000 years ago and probably to much earlier, Strasser reported January 7. Many of these finds closely resemble hand axes fashioned in Africa about 800,000 years ago by *H. erectus*, he said. *H. erectus* had spread from Africa to parts of Asia and Europe by at least that time.

Until now, the oldest known human settlements on Crete dated to around 9,000 years ago. Traditional theories hold that early farming groups in southern Europe and the Middle East first navigated vessels to Crete and other Mediterranean islands at that time.

"We're just going to have to accept that, as soon as hominids left Africa, they were long-distance seafarers and rapidly spread all over the place," Strasser said. Other researchers have suggested that *H. erectus* took rafts across stretches of sea in Indonesia about 800,000 years ago and that Neandertals crossed the Strait of Gibraltar perhaps 60,000 years ago.

Questions remain about whether African hominids used Crete as a stepping stone to Europe or, in a Stone Age Gilligan's Island scenario, accidentally ended up on Crete from time to time when close-to-shore rafts were blown out to sea, remarks archaeologist Robert Tykot of the University of South Florida in Tampa. Only in the past decade have researchers established that people reached Crete before 6,000 years ago.

Hand axes on Crete suggest early human activity there over 130,000 years ago.

Strasser's team cannot yet say precisely when or why hominids traveled to Crete. Large sets of hand axes found on the island suggest a fairly substantial population size, downplaying the Gilligan's Island scenario, in Strasser's view.

In excavations conducted near Crete's southwestern coast during 2008 and 2009, the team unearthed axes at caves and rock shelters. Most sites were in an area called Preveli Gorge, where a river has gouged layers of rocky sediment.

Stone Age artifacts there were excavated from four terraces along a rocky outcrop overlooking the Mediterranean. Tectonic activity has pushed older sediment above younger sediment on Crete, so 130,000-year-old artifacts emerged from the uppermost terrace. Other terraces had estimated ages of 110,000 years, 80,000 years and 45,000 years.

Intriguingly, Strasser noted, hand axes on Crete were made from local quartz but display a style typical of ancient African artifacts. "Hominids adapted to whatever material was available on the island for toolmaking," he proposed.

MEETING NOTES

Graffiti on the walls in Pompeii

Well-off homeowners living in the Roman city of Pompeii more than 2,000 years ago could read the writing on their walls, and apparently didn't mind the spontaneous scrawling. Citizens of Pompeii scratched out graffiti on walls of private residences to share creative greetings, welcomes and salutations to friends, Rebecca Benefiel of Washington and Lee University in Lexington, Va., reported on January 8.

Benefiel studied 41 examples of written graffiti in one house. Most graffiti appeared on walls in well-traveled areas, such as an entrance area and near stairways. She also identified 12 instances of graffiti images in the house. A few areas contained graffiti consisting of Roman numerals that were possibly used in number games, in Benefiel's view. — *Bruce Bower*

Zeus' altar of ashes

Excavations at the Sanctuary of Zeus atop Greece's Mount Lykaion reveal that ritual activities occurred there for roughly 1,500 years, from the beginnings of Greek civilization around 3,400 years ago until just before Roman conquest in 146 B.C. "We may have the first documented mountaintop shrine from the ancient Greek world," project codirector David Romano of the University of Pennsylvania in Philadelphia said January 8. Ritual ceremonies were conducted in a part of the open-air sanctuary called the ash altar of Zeus, the head god of Greek mythology. Romano's team reported initial evidence of ritual activity at the ash altar of Zeus in 2007. The new discoveries indicate that ancient Greeks kept returning to the sacred site for a remarkably long time. — *Bruce Bower*

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Matter & Energy

"It is quite remarkable to see a material in the lab behaving with such perfection." —ALAN TENNANT

Elusive symmetry appears in nature

Complex E_8 patterns detected in supercold physical system

By Rachel Ehrenberg

A beautiful math emerges from the acrobatic flips of supercold atoms in a magnetic field.

In the Jan. 8 *Science*, researchers report detecting an elusive, complex symmetry known as the E_8 Lie group, long analyzed on paper but never before seen in a physical system. The work suggests that this numerical grace may be hidden in other systems and may provide a mathematical link between quantum processes in matter and the physics of the cosmos.

"Finding a mathematically exotic symmetry in a regular material we can find on Earth — well, it is mathematically beautiful and very interesting," comments Robert Konik of Brookhaven National Laboratory in Upton, N.Y.

Scientists from England and Berlin began with chains of cobalt niobate, a magnetic material whose electrons have a preferred direction of spin — either up or down. The researchers chilled the cobalt niobate to 40 millikelvins (-273.1° Celsius) and applied a magnetic field. Without this external magnetic field, the spins of the electrons would all align in the same direction, as in an ordinary magnet. But an external magnetic field introduces a tension, and eventually the electrons prefer to align with that magnetic field instead of with their neighbors. The electron spins are associated with particle-like states, known as quasiparticles, in the system.

As the system approaches what's known as a quantum critical point, blocks of quasiparticles begin changing orientation, says study coauthor Alan Tennant of the Helmholtz Association of German Research Centers in Berlin. That's when the quasiparticles start resonating at mathematically intriguing frequencies. Two of the frequencies are in the ratio of the golden mean, the pleasing ratio of 1.618 often used in art and architecture. Ratios of the five frequencies found correspond to the complex E_8 Lie group symmetry.

"It is quite remarkable to see a material in the lab behaving with such perfection," says Tennant. Perhaps this symmetry will also emerge in other physical systems and shed light on bigger questions, he says.

Science & Society

For in-depth coverage of the Copenhagen climate meeting, visit **www.sciencenews.org/copenhagen**

Copenhagen climate summit yields 'real deal' to limit greenhouse gases

Nonbinding accord still needs beefing up, negotiators agree

By Janet Raloff

COPENHAGEN — Last month, after two weeks of heated — at times, intensely inflammatory — talks, representatives of 193 nations agreed to a bare-bones framework for an international treaty to curtail global warming. But even its proponents admit it falls short of what's needed.

The Copenhagen Accord, named for the Danish city in which it was forged on December 18, would cut releases of climate-altering pollutants by most of the world's leading greenhouse gas emitters. It also would establish a multibillion-dollar-per-year trust fund whereby industrial nations would finance efforts by the poorest countries to cope with a warming world.

"When we launched negotiations two years ago, in Bali, I was firmly convinced that we would be arriving in Copenhagen to adopt a legally binding instrument," says Yvo de Boer, the United Nations' lead climate official. De Boer is executive secretary of the United Nations Framework Convention on Climate Change, which administered the existing climate treaty, the Kyoto Protocol, and would also manage this successor. But the consensus statement just agreed to is "not an accord that is legally binding," he notes. "Not an accord that, at this moment, pins down industrialized countries to individual [emissions-reduction] targets. Not an accord that, at this stage, specifies what major developing countries will do."

Still, United Nations Secretary-General Ban Ki-moon says, "We sealed the deal. And it is a real deal. And we will try to have legally binding [language] as soon as possible — in 2010."

Draft language released early in the summit proposed strong, mandatory reductions in greenhouse gas emissions by industrialized nations. Within 40 years, they were to cut emissions by at least 75 — and up to 95 — percent relative to 1990 levels. The final accord makes no mention of those targets. Industrial nations must commit only to implementing voluntarily set emissions targets for 2020 (values that each nation is supposed to decide on by January 31).

Early drafts of the accord also would have required outside auditing of emissions reductions (including those by developing countries) and of developing nations' disbursements from a new, United Nations–managed Green Climate Fund. (That fund will provide up to $10 billion a year from 2010 through 2012 and up to $100 billion a year by 2020.) China called outside verification a deal-breaker. The accord now states that countries can audit themselves.

> **The Copenhagen agreement is "not an accord that is legally binding."**
> YVO DE BOER, UNFCCC

The challenge in developing a climate treaty with teeth is that the UNFCCC requires all participating nations to agree on the treaty's language. So any nation can veto a deal. And as of December 17 — the day before the climate summit was due to end — closing the meeting with no deal appeared to be a real, if embarrassing, possibility.

That day, Prime Minister Apisai Ielemia of Tuvalu vowed that his nine-island nation would block any accord that did not require "legally binding" emissions cuts and that did not state the goal of keeping the peak rise in average global temperatures "well below" 1.5 degrees Celsius. Not only did the final language nix legally binding requirements, but it also set the target for peak temperature rise at "below 2 degrees Celsius."

Also threatening to walk out on negotiations if the accord didn't mention a 1.5-degrees-Celsius limit on temperature rise (and establish a much bigger trust fund for developing nations) was President Hugo Chavez of Venezuela, along with representatives of other socialist and socialist-leaning Latin American nations and a Sudanese diplomat who chairs the G77, a large group of developing nations that frequently vote together owing to similar economic interests.

Yet all ultimately came around — sort of — by being persuaded that they just had to "take note" of the new accord. This phrase has "equal validity" to saying that negotiating nations "accept" the document, explains U.N. Assistant Secretary-General Robert Orr.

In U.N. parlance, taking note means nations can formally recognize a document without immediately deciding whether to accept any or all of its provisions, according to de Boer. Here, it allows the new "accord" to move forward without requiring participating nations to commit to adopting it.

The agreement's skeletal outline for global action, while far from ideal, creates "the ingredients of an architecture that can respond to the long-term challenges of climate change," de Boer says. "But not in precise legal terms. And that means that we have a lot of work to do on the road to Mexico" — where the next climate change summit will take place, at the end of 2010.

Jonathan Lash, president of the Washington, D.C.–based World Resources Institute, is more reserved about the new accord's prospects. Its significance is "likely to emerge in the next two months," he says, as nations exhibit their willingness to sign on to the new agreement and pledge emissions cuts. Only then, he says, will it become clear "whether this is the platform for worldwide actions to address climate or a failed political exercise." ■

Bob Vila endorses and recommends the famous EdenPURE® portable heater

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By John Whitehead, Media Services

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For more details on the amazing EdenPURE® GEN3 Quartz Infrared Portable Heater, here is my interview with Bob Vila, America's Favorite TV Home Improvement Expert.

Q. What is the origin of this amazing heating element in the EdenPURE®?

A. This advanced heating element was discovered accidentally by a man named John Jones.

Q. What advantages does this advanced infrared heating process have over other heating source products?

A. This infrared heating process was designed around the three most important consumer benefits: economy, comfort, and safety.

In the EdenPURE® process, electricity is used to generate a type of infrared heat which, in turn, creates a very safe heat.

Q. How can a person cut their heating bill with the EdenPURE®?

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End of interview.

The EdenPURE® will pay for itself in weeks. It will keep a great deal of extra money in a users pocket. Because of today's spiraling gas, oil, propane, and other energy costs, the EdenPURE® will provide even greater savings as the time goes by.

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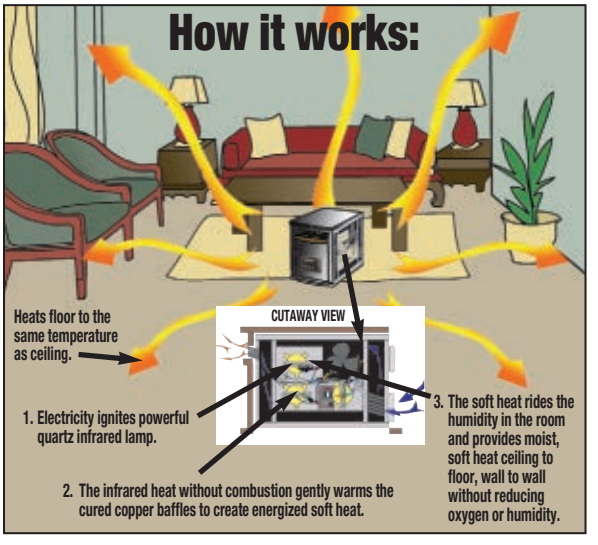
Pictured above is Bob Vila demonstrating the famous EdenPURE® GEN3 Model 1000 heater with a family. It saves big money on your heating bill while keeping you toasty warm with "heavenly heat".

How it works:



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The EdenPURE® has cut my gas bill to a third of what it was last year. ***Leslie Wilson, Vancouver, WA***

With our EdenPURE® heater our gas bill dropped so much that the gas company called us and said our gas meter must be broken and they wanted to replace it. ***John and Sandy Hopkins, Elyria, OH***

Average homeowner saves 10% to 25% monthly. This is an advertisement for the EdenPURE® Heater. All of the testimonials are by actual EdenPURE® customers who volunteered their stories, and were given another EdenPURE® heater as thanks for their participation.

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Let there be

In the beginning, the brain was a dark and shapeless void.

Then scientists deployed dyes, and lo, the intricate branching of brain cells called neurons was revealed. It was good but didn't show which cells rubbed branches with others.

After a time, scientists brought forth electrodes and functional MRI machines to eavesdrop on neurons' electrical chatter. It was good, but the message was hearsay. It could not show that any specific chitchat caused a particular behavior.

Then the scientists said let there be light, and a new age of neuroscience dawned. Now researchers create light-responsive molecules — or borrow them from microorganisms — to insert into animals' neurons. And light shines upon the molecules, giving scientists dominion over the brain cells' activity.

Harnessing light's power has given birth to a burgeoning new field called optogenetics, which allows scientists to control neurons in freely moving animals. Although the technology is new, it is already beginning to illuminate some of the darkest corners of the brain, such as the connections that guide movement or make memories and the neuronal circuits that go haywire in depression, addiction or schizophrenia. What scientists learn from the light-aided experiments may lead to refinements of existing therapies or to new treatments for nervous system disorders.

After its debut in 2002, optogenetics went through a development period. Scientists had to demonstrate that the technology could change activity of brain cells and behavior in moving animals. Only in the last two years have

Neurons (illustrated) made to produce certain proteins can be activated by light.

PASIEKA/SCIENCE PHOTO LIBRARY/GETTY IMAGES

light

New technology illuminates neuronal conversations in the brain

By Tina Hesman Saey

light-driven experiments delivered unexpected results about how the brain and nervous system work, elucidating causes and effects.

"It took a few years to go from potential to fruition," says neuroscientist Karl Deisseroth of Stanford University, a pioneer of the optogenetics movement. "We've turned a corner." Now, more than 500 laboratories are using optogenetics to probe the brains of mice, fruit flies, zebra fish and nematodes, and even to probe human neurons growing in lab dishes, to "get to the neural code for complex things, such as reward," he says.

Optogenetics may help neuroscience mature as a scientific discipline, says Gero Miesenböck, a neuroscientist at the University of Oxford in England and a founding father of the field. With the advent of optogenetics, he says, "neuroscience is now finally catching up to the widely held standards of proof in other fields of biology and chemistry to help establish causality."

Light-responsive molecules used in optogenetics experiments have two basic modes. Some are neuron activators. When a specific wavelength of light shines on the cells engineered to carry these molecules, a channel opens and allows positively charged ions to flow into the cell. "This happens to be the neural code for 'on,' " Deisseroth says. Other light-responsive molecules, when tickled with the correct wavelength of light, let negatively charged ions into the cell. The influx of negative ions silences neurons. Using combinations of the two types of molecules and different wavelengths of light, researchers can flip neurons on and off at will to find out how neurons interact with their neighbors.

For now, knowledge of those interactions is limited to small groups of neurons within more extensive brain circuits. But by flipping light-controlled switches, scientists may eventually construct a full diagram of the brain's wiring.

"The most exciting application right now is the ability to control the activity, remotely and noninvasively, of neurons," says Herwig Baier, a neuroscientist at the University of California, San Francisco. "It's like a functional MRI, except it's truly functional. You can really show causality."

Functional MRI has helped researchers peer into living brains, revealing which areas of the brain are active (*SN: 12/19/09, p. 16*). But optogenetics allows scientists to manipulate neurons instead of just observing them. Scientists can identify specific brain circuits, such as those that help fruit flies sing love songs or give fish their tail swish, as well as those that push mice into addiction or cause them to collapse into depression.

Optogenetics allows scientists to manipulate neurons instead of just observing them.

Flipping the switch

In 2008, Miesenböck and colleague J. Dylan Clyne of Yale University reported in *Cell* that they had used light to manipulate a brain circuit that controls courtship behavior in the fruit fly *Drosophila melanogaster*. Researchers had already known that one form of a protein called fruitless is made in some neurons in male fruit fly brains and that those neurons help regulate the wing vibrations that create the flies' mating songs.

This form of fruitless had been found in males but not females, and researchers think that the protein form helps wire males' brains to sing courtship songs. Females, scientists had thought, may lack the brain circuit for creating the mating serenade.

Clyne and Miesenböck engineered fruit flies of both sexes to carry a light-responsive protein in the neurons that make this fruitless in male flies. A pulse of UV light activated the neurons, causing males to immediately beat their wings. But female flies began to sing sultry music (to a fruit fly), too. The result indicates that male and female flies have the same underlying brain circuitry, a surprise to the researchers.

"We really had no inkling that there is a unisex structure that you can switch to male or female behavior," Miesenböck says. "It's really an elegant solution."

Though Miesenböck doesn't much care about the love lives of fruit flies, studying the insects may help him figure out how the brain ticks.

He and his colleagues are using the technology for other basic biology problems as well. Memory studies, for instance, usually focus on the effect of disrupting a particular gene or use psychological tests to try to determine how memories are made. But neither of those types of experiment reveals which neuronal circuits are activated during the memory-making process.

"These approaches, I feel, leave the black box pretty firmly shut," Miesenböck says. Genetic experiments that disrupt a gene and shut down brain cell activity aren't as informative as finding out what happens when a particular circuit is activated, he says. "There are many ways you can break something, but often there's only one way to make it work."

His team plugged in light-activated molecules to create false smell memories in fruit flies. Formation of smell memories is known to require dopamine, which interacts with cells in brain structures known as mushroom bodies. But researchers didn't know exactly which neurons make the dopamine, or the identity of the cells within the mushroom bodies that receive the chemical's message.

By engineering different sets of neurons to respond to light and turning those neurons on at different times, Miesenböck's team tracked the source of particular smell memories to a cluster of 12 dopamine-producing cells known as the PPL1 neurons. By triggering those cells, researchers created an aversive memory akin to that created by pairing an odor with a shock, the researchers reported in the Oct. 16 *Cell*.

The experiments identified the signal that teaches flies not to like a particular smell but didn't uncover the source of the signal, Miesenböck says. "We would like to meet the teacher." Further light-guided experiments might eventually garner such an introduction.

Optogenetics is helping scientists more precisely probe the activity of nerve cells in the spinal cord, too.

Baier and colleagues recently got a bright idea about the raison d'être of some spinal cord neurons with a name but no known function. Kolmer-Agduhr cells are found in the spinal cords of all vertebrates, but no one knew why the cells are there or what they do. Baier's team inserted a light-activated molecular switch, known as LiGluR, into the Kolmer-Agduhr cells in zebra fish and then flipped on a UV light.

"The results were really astounding," Baier says. When the light came on, the fish's tails began to swish back and forth in swimming mode. With light activation, the cells still caused the swimming movements even when the connection between the brain and spinal cord was severed, the team reported September 17 in *Nature*. "All together, these observations show that the forward swim can be attributed specifically to the activation of the Kolmer-Agduhr cells," the researchers wrote.

With light, a team turned on Kolmer-Agduhr nerve cells in zebra fish and found that the cells made the fish tails swish (images captured from swishing video shown).

But the experiments showed that the cells are not involved in all types of movement. For example, the cells didn't help when the fish sensed a touch and bent their tails in a C-curve to escape predators. Now Baier and his colleagues are probing zebra fish brains with light to dissect the pathways that control motion. Eventually, such experiments may help lead to a better understanding of movement disorders in people.

Light shed on brain disorders

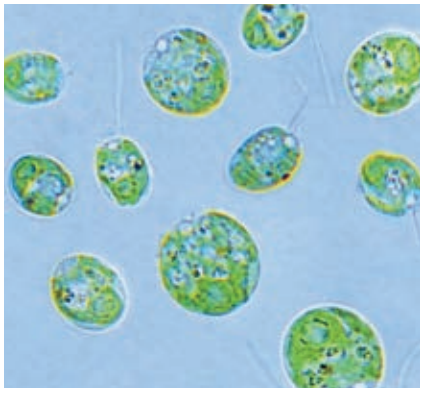
Deisseroth's group has already illuminated brain circuitry involved in Parkinson's disease (*SN: 4/11/09, p. 11*). The team found that stimulating certain neurons in the motor cortex could quell Parkinson's-like symptoms in mice. The discovery, reported online last March in *Science*, could lead to the development of less invasive treatments for the disorder than the currently used deep-brain stimulation.

Other brain disorders, including mental illnesses, may arise when certain circuits misfire. Scientists are tracking down these short-circuits by following optogenetically illuminated pathways. Previous work had shown that chronic social stress — the equivalent to being constantly bullied in humans — can make mice depressed. That depression is associated with lower activity levels of certain genes in the part of the brain called the medial prefrontal cortex, as well as other brain changes.

Researchers at Mount Sinai School of Medicine in New York City engineered mice so that their brain cells make a light-activated protein found in a single-celled alga called *Chlamydomonas reinhardtii*. The protein, channelrhodopsin-2, responds to certain wavelengths of blue light by letting in positively charged ions and turning neurons on. When housed with bigger, tougher mouse bullies, the mice became antisocial, a sign of depression. But shining a blue light on the medial prefrontal cortex turned on cells making channelrhodopsin-2, and that stimulation reversed the depression about as well as an antidepressant drug, Herbert Covington of Mount Sinai reported in Chicago in October 2009 at the annual meeting of the Society for Neuroscience. The work may help scientists find the cells where changes that lead to depression first occur.

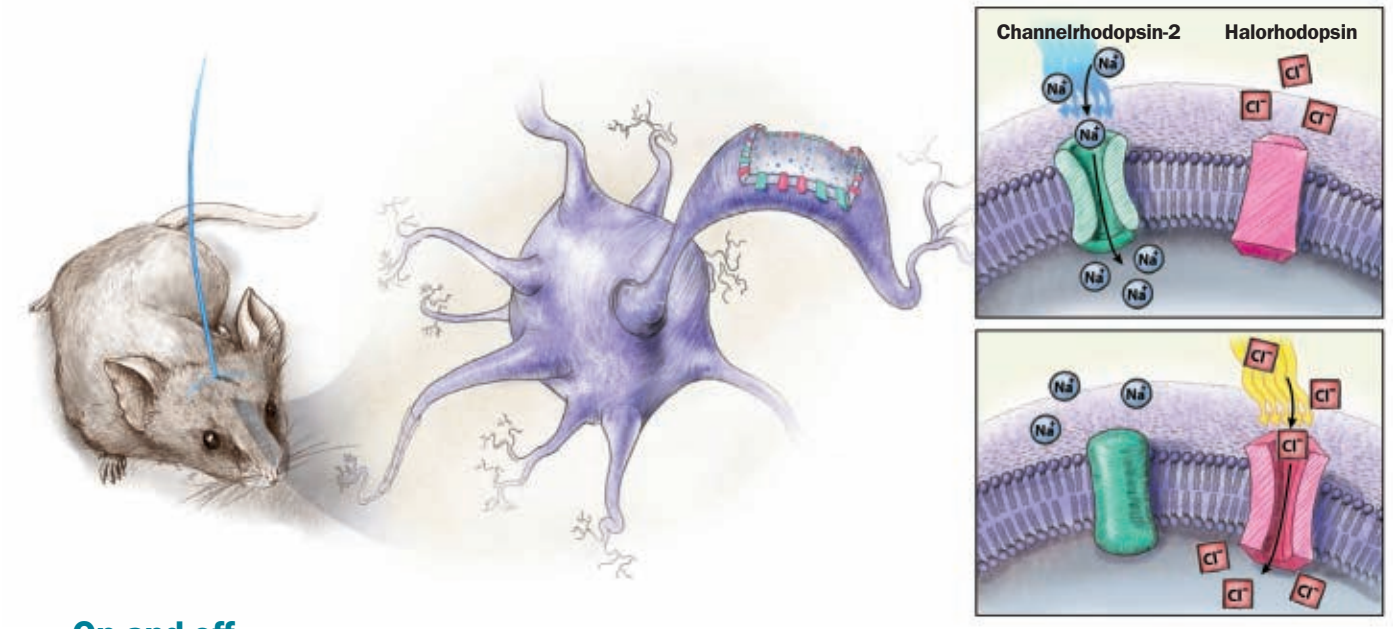
On the flip side of depression's darkness is the glow of reward. No one has precisely mapped how the reward system is wired, but when it goes awry, it's a major player in addiction. Garret Stuber of UC San Francisco and colleagues are tracing reward circuits in the brains of mice by following the light.

Stuber's team injected a virus carrying channelrhodopsin-2 into the amygdala, an emotion-processing center, in the brains of mice. The virus can travel in the brain along fibers that connect the amygdala to other brain regions, including the nucleus accumbens, a part of the brain previously shown to be important in



Optogeneticists use the light-activated protein channelrhodopsin-2, made by *Chlamydomonas reinhardtii* (shown).

FROM TOP: COURTESY OF H. BAIER, C. WYART *ET AL.*; PASCAL GOETGHELUCK/PHOTO RESEARCHERS, INC.



On and off Once a mouse is genetically engineered to produce light-activated proteins in brain cells, the right wavelength of light can turn neurons on or off. Blue light causes the protein channelrhodopsin-2 (green) to change shape, allowing positive ions to flow into the cell. Halorhodopsin (red) changes shape with yellow light, allowing negative ions to flow in. Positive ions can activate a cell; negative ions can turn the cell off.

addiction. As the virus spreads, it infects other cells in the region the researchers are looking at.

Shining a blue light on the nucleus accumbens activated connections to the amygdala, rewarding the mice. Mice trained to poke their noses into a hole to trigger a pulse of light on the nucleus accumbens kept going back again and again for another flash, indicating that the light flashes caused a reward response. But mice that got a flash of light to stimulate connections between the nucleus accumbens and the prefrontal cortex didn't seem to have a rewarding experience, Stuber reported at the neuroscience meeting. That suggests that the connections between the prefrontal cortex and nucleus accumbens are not involved in this reward circuitry.

Optogenetics can also help scientists learn more about circuitry associated with normal brain functions, says Michael Häusser of University College London. He and his colleagues are investigating a long-standing debate in neuroscience about how the brain recalls memories.

Learning is thought to activate networks of neurons, and scientists think activating subsets of the cells in the networks may reactivate a memory. Before optogenetics, there was no way to directly test that hypothesis.

Häusser's group presented preliminary, unpublished evidence supporting the idea at the neuroscience meeting. The team injected a piece of DNA into the hippocampus of mice that would produce channelrhodopsin-2 wherever neuronal remodeling associated with learning occurred. The hippocampus is an area of the brain known to be important in learning and memory.

The next day, the mice were trained to fear a shock on the foot. Mice that learned to connect an audio tone and the shock froze, a known response to fear, when they heard the tone, even if no shock followed.

Light shining into the hippocampus could also activate the cells that made the mice freeze, indicating that those cells were involved in learning to fear the shock. The researchers also tested whether activating any cells in the hippocampus could cause the fear response. Only those cells involved in the initial learning could make mice freeze. The researchers further found that activating just 100 to 200 cells is enough to reproduce the behavior, suggesting that the reactivation theory could be correct.

Miesenböck thinks optogenetics may help settle this reactivation debate and answer other basic questions about brain biology, such as whether the precise timing of each spike of electricity a neuron sends out is important, or neighboring cells listen only to the average pattern of activity. Optogenetics isn't yet precise enough to answer that question and has some other limitations, Miesenböck says. He outlined the technique's strengths and weaknesses in the Oct. 16 *Science*.

"Optogenetic technology, despite all of its refinement, is not able to control activity of individual members of a group of neurons," he says.

And for all its power, it's not intended to be a therapeutic tool; that would require gene therapy and brain surgery. But optogenetics is helping scientists discover things about the brain and nervous system that no one ever knew before. And, for that reason, it is good. ■

Explore more

- YouTube video of a mouse whose behavior is being altered through optogenetics: http://bit.ly/8Usvvj
- Karl Deisseroth talks about controlling the brain with light: http://bit.ly/6tNKrv

NICOLLE RAGER FULLER

DRESSING UP dinos

Adding soft tissue to bone helps scientists, paleoartists bring ancient creatures to life

By Sid Perkins • Illustration by Julius T. Csotonyi

Conditions resulting in the near-complete preservation of a dinosaur are rare. This artist's illustration depicts a young hadrosaur that was discovered in 2001 after becoming mummified 77 million years ago.

Fossils of an ancient animal don't typically include much more than the creature's hard parts — sometimes intact, but often shattered to smithereens. Lucky paleontologists may stumble upon a well-preserved, nearly complete skeleton that offers a rough idea of an animal's size and shape. But fossils that preserve soft tissues — skin, flesh, feathers — are the rarest of the rare. These geological treasures form and survive only under special environmental conditions that scientists are just now beginning to understand.

Bones give just an overall hint of what an animal such as a fearsome *Tyrannosaurus rex* or a three-horned *Triceratops* might have looked like. Soft tissues, though, disclose more details. The recent discovery of a *Triceratops* fossil that included skin impressions provided surprising information: The creature may have sported bristlelike structures. "The skin is unlike anything we'd expected," says Bob Bakker, a paleontologist and a visiting curator at the Houston Museum of Natural Science.

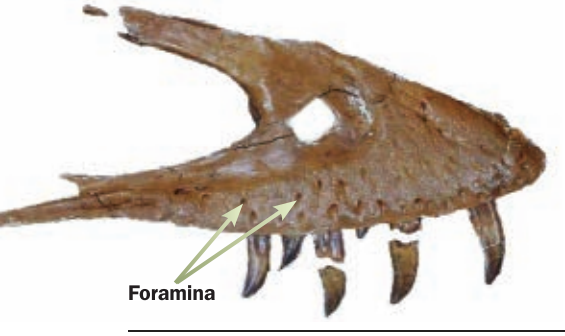
And sometimes soft tissues offer hints about how a creature might have functioned, lived and behaved. The size, shape and arrangement of feathers on an ancient dinosaur, for example, can suggest whether those structures aided flying and gliding, as in *Microraptor*, or whether they played a role in display, as in *Caudipteryx*.

Scientists are increasingly turning to new techniques to make up for the dearth of soft tissues preserved in the fossil record. Some investigate dinosaurs' closest modern-day relatives, including crocodiles and birds. These studies hold clues to not only appearance, but also function — the extent and type of flesh present around a dinosaur's teeth and jaws could suggest whether a creature could seal its mouth while chewing and, in turn, what types of food the animal might have eaten.

Other researchers use computers to add virtual flesh and muscle to bones. By laser-scanning museum specimens, scientists can now more accurately construct 3-D models of dinosaurs that provide a reasonable range of weight estimates for the creatures. Information garnered from other studies — how much cartilage a dinosaur's knee might have had, perhaps, or the amount of muscle that once surrounded its bones — further flesh out cyberdinos. When fed into biomechanical simulations, such data show how quickly or efficiently a dinosaur might have moved.

Ultimately, these findings make it into the hands of paleoartists, the sketchers, sculptors and animators who work independently or with scientists to generate a picture of the past and bring long-extinct creatures back to life.

Holey hints Scientists often rely on bones to figure out how dinosaurs looked. The number of holes called neurovascular foramina in a creature's facial bones (part of *T. rex* upper jaw shown) can hold clues about soft tissues.



Signs of attachment

A dinosaur's bones, regardless of how they're found in rocks or mounted in museums, weren't isolated structures. Like all vertebrates' skeletons, they were once nourished by blood vessels, riddled with nerves and linked to each other with ligaments and to muscles with tendons. Each of these interfaces leaves a trace

on a well-preserved fossil, says Ashley C. Morhardt, a vertebrate paleontologist at Western Illinois University in Macomb.

Small openings called neurovascular foramina pepper the facial bones of vertebrates. These holes — typically around 0.2 millimeters across, about the diameter of the body of a sewing pin, but sometimes larger — make space for the arteries that supply blood to the lips and cheeks and for the nerves that allow for sensation, Morhardt says. The number of neurovascular foramina on the bones around a creature's mouth relates to the type and amount of overlying soft tissue, she and her colleagues reported in September in Bristol, England, at the annual meeting of the Society of Vertebrate Paleontology. By counting the foramina on a fossil's facial bones, the team suggests, scientists can start to reconstruct a dinosaur's countenance.

During the study, the researchers dissected modern animals with different types and amounts of facial tissue and then counted foramina. Most creatures that had a toothy smile with exposed teeth and little if any soft tissue around the mouth, such as crocodiles and their relatives, had more than a hundred small foramina on each bone around the jawline. For those with beaks made of nonpliable material, such as birds, turtles and tortoises, average foramina counts on each facial bone ranged from 50 to 100.

Most mammals, which have flexible cheeks and lips, typically had fewer than 50 foramina per facial bone. Sea lions were an exception to this rule, however, probably because they forage in deep water where it's dark and therefore depend on whiskers and other sensory structures in the lips to locate food, Morhardt says. Lizards and snakes, which have liplike, fleshy tissues that cover the teeth and make an airtight and watertight seal, usually have no more than a dozen or so foramina.

Based on these trends, the researchers proposed at the vertebrate paleontology meeting that *Herrerasaurus*, an early predatory dinosaur with few neurovascular foramina, had lizardlike lips. *Camarasaurus*, a large herbivorous sauropod with peglike teeth, probably had fleshy cheeks that could form a seal and hold a mouthful of vegetation. For *Triceratops*, another vegetarian, the data aren't so clear: These dinos could have had either lizardlike lips or small cheeks. "It's pretty obvious that they had some kind of extra-oral covering," Morhardt says. "We just haven't been able to tease out what kind."

Knowing the type and amount of soft tissue surrounding the mouth helps scientists picture the dinosaurs and provides clues about how dinosaurs fed and what they ate, says Matthew Bonnan, a paleontologist at Western Illinois University and Morhardt's graduate adviser. By counting neurovascular foramina on

Say aaah Analyses of modern-day species suggest a correlation between the number of neurovascular foramina in facial bones and the type of soft tissue around the mouth. With few of these holes for blood vessels and nerves, *Herrerasaurus* may have had lizard- or snakelike lips. *Camarasaurus* had more foramina, suggesting fleshy, mammal-like cheeks. Turtles and birds had even more foramina, and alligators, with bare-toothed grins, had the most.

Aardonyx, a recently described ancestor of sauropods, he and his colleagues inferred that the creature had lips but didn't have fleshy cheeks. Without that constraint on its gape, the dino could have opened wide to gather large mouthfuls of browse — an ability that may have set the evolutionary stage for subsequent sauropod species to grow exceptionally large (*SN Online: 11/10/09*), the team reported online November 10 in *Proceedings of the Royal Society B*.

Such insights aren't limited to faces, Bonnan notes. The surface texture of well-preserved limb bones holds information about where muscles attached and how big — and powerful — those muscles might have been.

Know what's missing

Though most of an animal's soft tissues decompose after death, some partially mineralized bits have a head start on fossilization and become preserved. These remnants may provide hints about tissue that's missing, Bonnan says.

While it's easy to measure the cartilage in a fossil, for example, it's often difficult to estimate how much uncalcified — and now missing — cartilage was present to begin with. That, in turn, makes it difficult to ascertain the spacing and positioning of limb bones and, from that, the efficiency of a creature's movement.

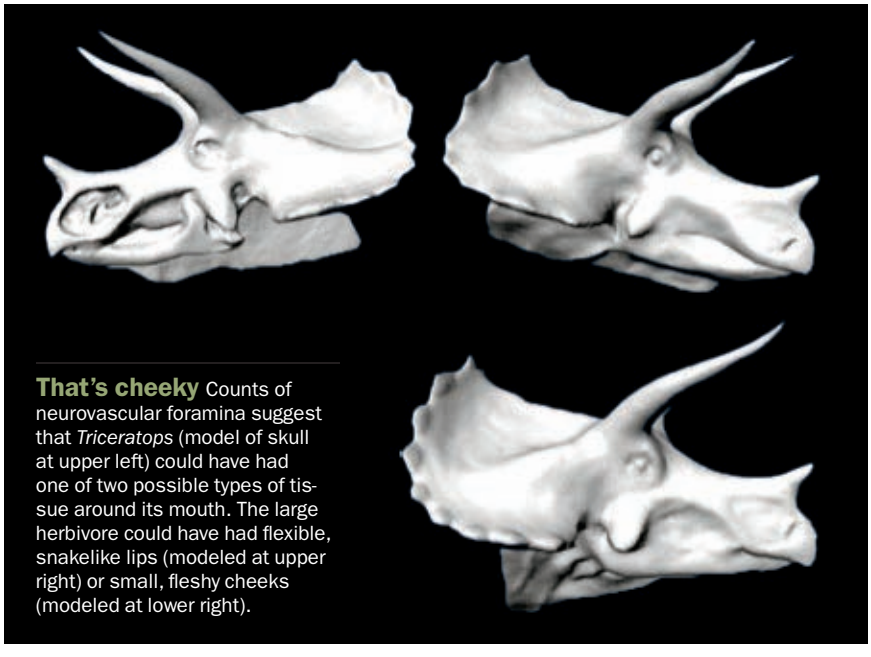
Previously, scientists looked to general similarities among modern creatures and employed a lot of informed guesswork and trial and error to fit bones together. Now, Bonnan and his colleagues have come up with detailed methods to better estimate how much cartilage may have been present in a dinosaur's joints. Once again, the team reported at the paleontology meeting in Bristol, the technique stems from analyses of modern-day dino relatives.

For their study, the researchers looked at joints from the front and hind limbs of alligators, as well as those in the wings and legs of ostriches and helmeted guinea fowl. First, the team measured the total amount of cartilage present in recently dissected joints. Simmering the bones at 60° Celsius for 24 hours removed the uncalcified cartilage but left calcified tissue intact. "The lab smelled like bad chicken soup for quite a while," Bonnan admits.

Removing the uncalcified cartilage from the joints of alligators shortened the humerus, the bone analogous to the one in the human upper arm, by about 5 percent, the team found. In the helmeted guinea fowl, removing that tissue shortened the limb bones by around 8 percent, and in juvenile ostriches, it trimmed the bones' length about 15 percent. With this information, the team suggests, scientists can estimate the amount of uncalcified cartilage missing from a fossil limb bone and reconstruct the creature accordingly.

"If you want to be accurate, you need to account for these things," says Tyler Keillor, a paleoartist at the University of Chicago. "What is the missing joint surface? How much space is there going to be? How would that have affected the range of motion?" Answering such questions helps scientists get a well-developed idea of how a dinosaur functioned as a living creature, he notes.

Scientists have been attempting to reconstruct ancient creatures by studying



That's cheeky Counts of neurovascular foramina suggest that *Triceratops* (model of skull at upper left) could have had one of two possible types of tissue around its mouth. The large herbivore could have had flexible, snakelike lips (modeled at upper right) or small, fleshy cheeks (modeled at lower right).

TOP, FROM LEFT: EKRATZIG/ISTOCKPHOTO; OARIFF/ISTOCKPHOTO; WRANGEL/ISTOCKPHOTO; AWC0007/ISTOCKPHOTO; TRICERATOPS: T. KEILLOR

modern ones since the 1790s, says Bakker. The general arrangement of muscles, he notes, is the same for creatures as diverse as the salamander and the rhino. "We can reconstruct about 95 percent of their body with great precision," he adds. "The scalpel is still one of our best tools." New studies such as Bonnan's and Morhardt's are fleshing out some of the remaining details, he says.

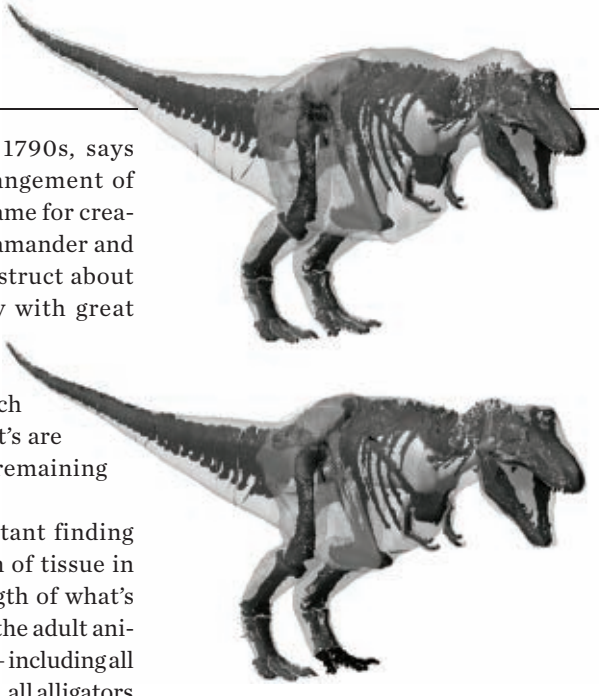
A possibly more important finding relates to the distribution of tissue in joints, not just to the length of what's missing, Bonnan says. For the adult animals that the team studied — including all of the helmeted guinea fowl, all alligators and one ostrich — the shape of the uncalcified cartilage in each joint showed little difference from the shape of the underlying calcified tissue. That was especially true for those creatures' weight-bearing joints, such as a biped's hind limbs, Bonnan notes.

Analyses also show that the overall distribution of cartilage provides insight into the forces that joints experience on a day-to-day basis. This finding should enable scientists to more accurately assess the posture of ancient creatures, and paleoartists to more accurately depict them, Bonnan says.

Model behavior

The posture of a dinosaur, as well as the size, shape and weight of its limbs, would have substantially affected how the creature moved through its environment. Until recent decades, most scientists thought that dinosaurs such as *Triceratops* were slow, lumbering creatures with a sprawling, crocodile-like posture. Evidence now indicates that *Triceratops* stood, walked and maybe even ran with its limbs beneath its body (*SN: 11/4/00, p. 300*).

Using detailed analyses of modern creatures, such as those by Bonnan and Morhardt, scientists can virtually add soft tissue to a dino's skeleton. Then, with sophisticated computer models similar to those that evaluate the performance of cars and aircraft, paleontologists can readily assess just how much a dinosaur might have weighed or how fast it might have moved. Recently, Phil Manning, a paleontologist at the University of Manchester in England, and his colleagues used such models to analyze *T. rex*, among other dinosaurs.



Adding meat Computer models put virtual flesh onto bones, providing estimates for how much dinosaurs might have weighed (hefty *T. rex at* top, slender version at bottom).

K. BATES *ET AL./PLOS ONE* 2009

First, the team scanned museum specimens with lasers to create high-resolution, 3-D models of the dinosaurs' skeletons. Data from studies of living creatures, Manning notes, allowed the team to account for low-density spaces such as lungs, air sacs and even sinuses.

One of the specimens the team analyzed — the second-largest *T. rex* ever discovered, a beast nicknamed Stan — is 11.9 meters long. Stan weighed somewhere around 7.6 metric tons (about 40 percent more than the average African bull elephant), the researchers reported last year in *PLoS ONE*. Each of Stan's legs weighed more than 1 metric ton, the team estimates.

Long muscular limbs can give a dinosaur power, but at the cost of speed: The fleshier a limb is, the more energy the creature must expend moving it back and forth, Manning says. Previous studies have suggested that *T. rex* could run only slowly if at all (*SN: 3/2/02, p. 131*), and Manning agrees: "The smaller, more gracile theropods will have the maximum running speed. When you get to something the size of *T. rex*, they're not going to be the top sprinters.... They were bloody powerful organisms, but they were not built for speed."

Real-world evidence can lend credence to such computer models. A good simulation of a walking dinosaur, for instance, should be able to reproduce a set of footprints with the same size and spacing seen in the fossil record. If the two don't match, the researchers can tweak the model, thereby improving its performance, Manning notes.

Knowing the type and amount of soft tissue that cloaked a dino's bones helps scientists sift through hypotheses about dinosaur anatomy and behavior. Whether a creature could have closed and sealed its mouth has profound implications, says paleoartist Keillor. "If you don't have a sealed mouth, how can you efficiently sniff?" he asks. "How do you keep from drying out in an arid environment?... It's an interesting mental exercise."

Such scientific findings are a boon for paleontologists trying to understand the past and for paleoartists trying to depict it, whether they represent the dinosaurs in a hyperrealistic style or in a highly stylized fashion.

"Pictures really help paleontologists communicate with the general public," says Robert Walters, a paleoartist based in Philadelphia. "You can write and describe it any way you like, but you really need to see the pictures to understand the structure of the animals."

And new technologies such as virtual reconstructions allow scientists to reexamine things in ways that couldn't be done before, he adds.

"Without the information that scientists develop, we'd be dead in the water," Walters says. "We'd just be making up dragon creatures." ■

Explore more

- Phillip Manning. *Grave Secrets of Dinosaurs: Soft Tissues and Hard Science*. National Geographic Books, 2008.
- Robert Walters and Tess Kissinger's dinoart webpage: www.dinoart.com

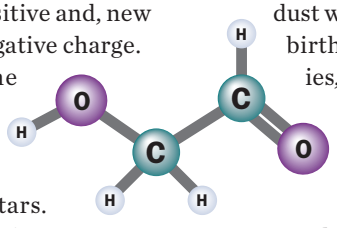
The final chemistry frontier

Molecules of the interstellar medium must break the rules to make the stuff of space

By Rachel Ehrenberg

The landscape could be the backdrop of a postapocalyptic film. It's an environment of extremes, blasted by intense radiation, fierce winds and shock waves from violent explosions. Yet within this desolation, species persist. Not only are there ordinary, familiar faces, there is also, evidence suggests, a motley crew: galactic gangs that would make Mad Max cringe. Some are decked out in metal; others are radicals itching to react, amped up with positive and, new research shows, even negative charge.

These species are the molecules of space, the cosmic chemicals that dwell in the vacuous netherworld between stars. After decades of cataloging these chemical specimens, scientists are now bracing for a torrent of data that may lead to a better understanding of the reactions that create and destroy cosmic compounds. Researchers are zooming in on the renegade reactive species, incorporating these players into models of the life cycles that govern space chemistry. The spiky, electrified characters may be major interstellar players in the formation of larger, more complex molecules — and could perhaps be the sparkling forerunners of life.



Glycolaldehyde

The chemical inhabitants of space are intimately linked to star formation and the greater cosmic cycle that gives rise to planetary systems. Scientists hope that the chemical exploration of the interstellar medium with its gas and bits of dust will reveal clues about the birth and evolution of galaxies, stars and planets. Added to this pursuit is the thrill of pushing the chemical envelope, probing an unmapped chemical frontier. It is an endeavor that will be aided by new telescopes, novel lab techniques and theory from astronomy and beyond.

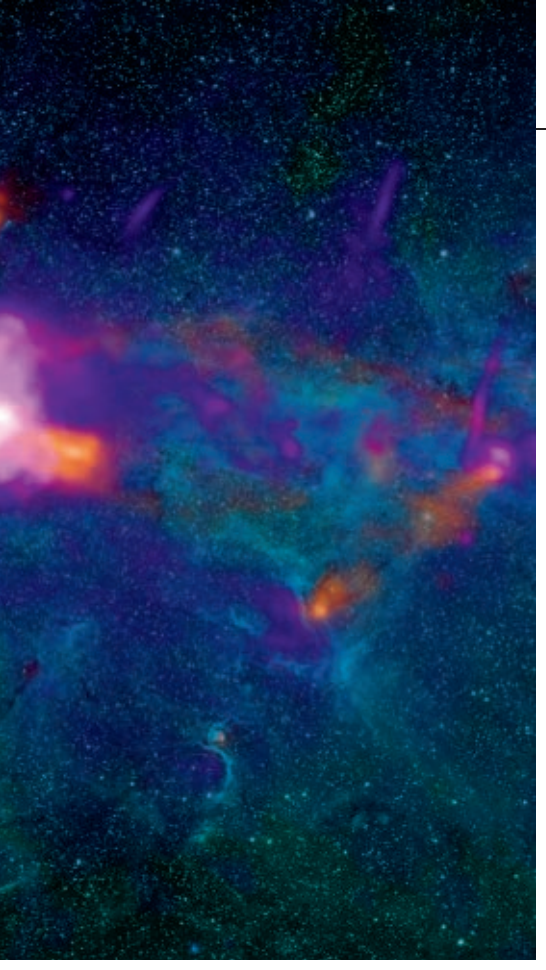
"We're trying to understand and attack fundamental chemistry principles," says astrochemist Anthony Remijan of the National Radio Astronomy Observatory in Charlottesville, Va. "We're taking the most fundamental chemical principles that we all know and love and seeing if they hold up in the extreme conditions of interstellar space."

Cosmic vagrants

The harsh environments of space pose challenges for both the molecules that live there and for the scientists studying them. Space is, well, spacious, making it hard for compounds to connect. Temperatures are extreme and pressures can be exceedingly low. In space, some molecules tumble through desolate regions in the form of gas; others dwell and react on bits of icy dust — lifestyles seldom seen on Earth.

"On Earth, it's always liquid phase, liquid phase, liquid phase," says chemist Brooks Pate of the University of Virginia, also in Charlottesville. "But that's the one thing you don't get in space. It's all gas phase and surface chemistry. This leads to a whole other type of chemistry that you don't see in terrestrial conditions. It's not like there are new physical laws. It's the physical conditions where the reactions go on that are quite different."

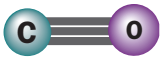
FROM TOP: RADIO-SUBMILLIMETER-INFRARED COMPOSITE BY ADAM GINSBURG/ UNIV. OF COLORADO AT BOULDER AND COURTESY OF NRAO, ASSOCIATED UNIVERSITIES INC.; A. NANDY



In space, compounds can brew in the dust and gas of regions such as the Milky Way's galactic center and surrounding zone of active star formation.

Terrestrial chemistry often happens in solution, where no molecule is ever alone. But within the interstellar medium, vast distances separate molecules — if two people were a proportional distance apart, one might be standing on the Earth and the other on the moon.

An emerging picture reveals how molecules in space use flashy charges to woo each other from a distance. Collisions with particles, ultraviolet starlight and cosmic rays, for example, can leave a molecule charged. Until recently, only neutral and positively charged species had been detected. Researchers thought radiation would quickly strip a molecule of the extra electrons that confer a negative charge. But now a handful of molecules with negative charges have been found.



Carbon monoxide

Getting decked out with charges gives species an advantage, making them visible from afar or allowing them to tunnel through ice. Most earthly molecules are neutral. They don't stand out. These chemical wallflowers need to be within a few nanometers of each other to interact, says Pate. But space's highly reactive species can be drawn to each other from as far as a hundred nanometers away.

Although these fired-up species sound like cosmic vagrants, they do exist on Earth, Pate says, but in very small concentrations and often only on the way to becoming something else. In that regard, the chemistry of space is like watching Earth chemistry in slow motion. On Earth a molecule might exist for a nanosecond before colliding with another molecule. In space the time between collisions can be weeks to years. A molecule is more likely to encounter a partner if it is decorated with charges.

Only the strong survive

Evidence suggests that the cold, dark clouds that gather in the interstellar medium are the electrical tattoo parlors of the cosmos — hot spots for charge decoration. These clouds offer a refuge for the resilient few who survive the shocks and radiation of the interstellar medium.

The interstellar dust and gas is created locally — born of dying stars. For much of their lives, stars burn hydrogen into helium. After the hydrogen is consumed, helium converts to oxygen and carbon (if the star is massive enough, it keeps brewing and more elements are formed). Because there's more oxygen in the galaxy than carbon, scientists had thought that this carbon wouldn't be available for organic chemistry. It would just get snapped up by oxygen, forming carbon monoxide. But in the outflow of some stars, the oxygen-carbon ratio is tipped just enough that chains of carbons can form. The stellar ejecta of these extreme carbon stars throws carbon into the interstellar medium where it can feed the creation of carbon-rich molecular clouds.

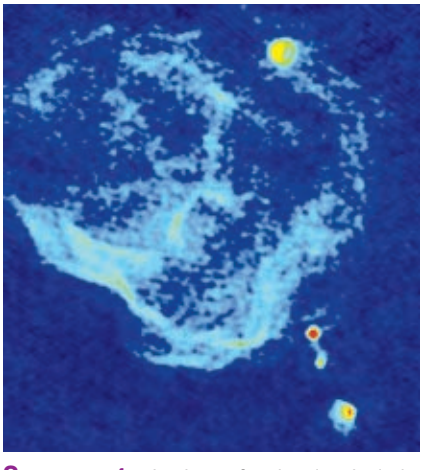
Going from stellar outflow to the diffuse interstellar medium is a journey from cradle to grave for many molecules, says Scott Sandford of the NASA Ames Research Center in Moffett Field, Calif. Anything drifting in this interstellar wasteland experiences intense ultraviolet radiation, cosmic ray bombardment and shock waves that smash anything in their path. "The diffuse ISM isn't about the production of things, it's about winnowing," says Sandford. "A lot of weaklings are weeded out."

The bits of compounds shattered in the violent processes of the interstellar medium can gather into clouds along with resilient, extra-large molecules, such as polycyclic aromatic hydrocarbons or PAHs. On Earth, these compounds of fused six-carbon rings (picture chicken wire) are combustion-related pollutants, maligned for their carcinogenic nature. But in space, PAHs are emerging as chemical stars, molecules that may contain a good portion of the interstellar medium's carbon.

It's within the interstellar clouds that the chemistry picks up, says Sandford. "Starlight is blocked and suddenly molecules you make aren't destroyed," he says. "They can survive, and then you can get more compounds because there's much more material in a smaller area."

Cloud chemistry

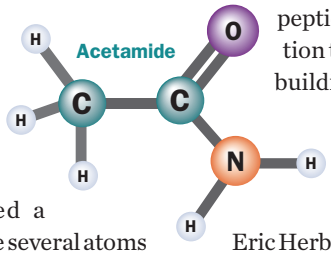
Many of the more complex molecular species are found in these cold, dark clouds. Since the hunt for interstellar



Space sugar Legions of molecules, including the simple sugar glycolaldehyde, have been detected in a molecular cloud (blue indicates weaker radio emissions, red stronger) within the constellation Sagittarius.

MOLECULES: A. NANDY; BOTTOM RIGHT: COURTESY OF NRAO, ASSOCIATED UNIVERSITIES INC.

molecules began in earnest in the 1960s, tuning in to the molecular symphony that pours from a region of dense clouds within the constellation Sagittarius has revealed a wealth of species. Many are several atoms strong. A note-by-note fingerprint — the spectra of energy emitted as a molecule twists and shouts — can be determined in the lab, and then that spectral signature can be detected in the sky, and vice versa. In April, an international team of astronomers viewing the Sagittarius region with the IRAM 30-meter telescope on Pico Veleta in Spain reported detecting ethyl formate, which helps give raspberries their fruity flavor here on Earth. And using the Robert C. Byrd Green Bank Telescope in West Virginia, Remijan and colleagues detected acetamide, one of two known interstellar molecules with a peptide bond, the same connection that links amino acids, the building blocks of proteins.



Evidence suggests that clouds are where a lot of the hard-core exotics get their stripes, says Eric Herbst of Ohio State University in Columbus. As the clouds warm, large neutral molecules can build up from small charged precursors, including perhaps the newly discovered negative species such as C_6H^-, a carbon chain anion, Herbst and colleagues reported last year in the *Astrophysical Journal*. Incorporating negatively charged species into models of the chemistry of dark clouds makes the models more accurate in predicting the observed abundance of certain compounds, the team reports.

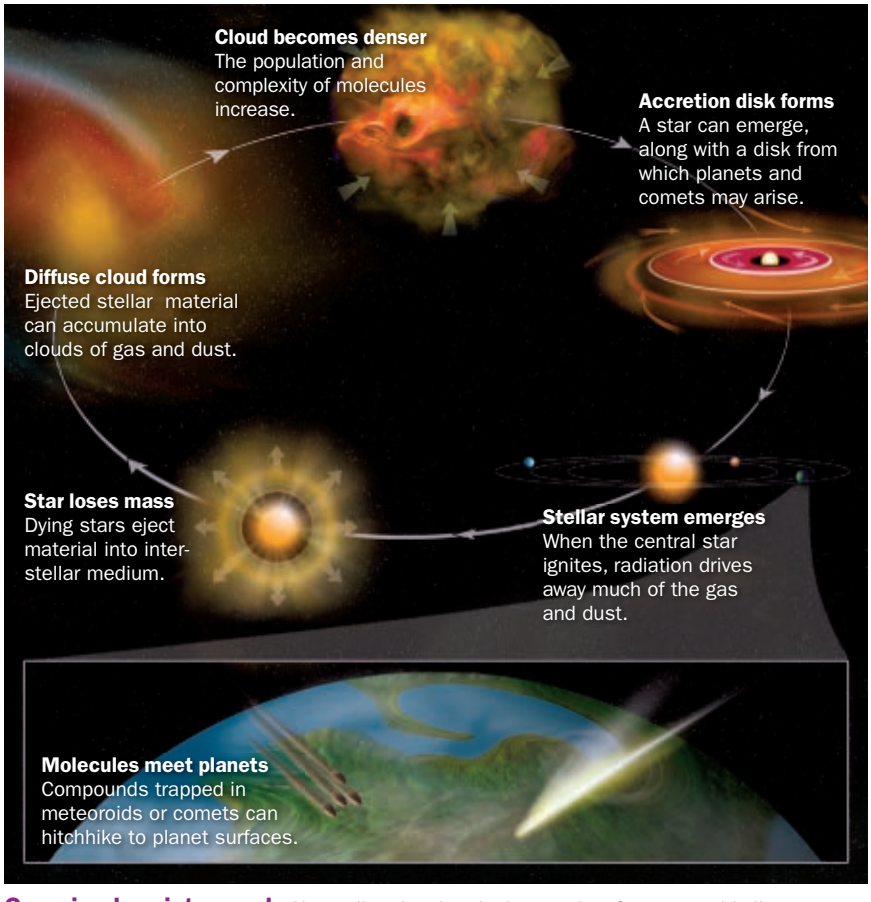
A common way for these charged-up species to get their zing appears to be via protonated molecular hydrogen, H_3^+, says Pate. This molecule of three hydrogen atoms with a positive charge is one of the most abundant ions in the universe and forms when H_2 is bombarded with cosmic rays that can penetrate dense clouds. Protonated molecular hydrogen is an acid, just itching to donate protons to other molecules, a gift that can help get reactions going by minimizing the energetic hump molecules must surmount in order to do their stuff.

"H_3^+ may be the greatest catalyst of the interstellar world," says Pate.

Chains of reactions starting with H_3^+ can lead to a collection of complex species, notes Herbst, though many of the reactions are poorly understood. And when H_3^+ passes on a proton, it also confers reactivity. Pate is investigating how another abundant molecule, methanol, acquires reaction-spurring activities when it picks up extra protons.

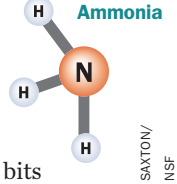
PAHs may also be catalysts that spur the formation of protonated hydrogen, which can then enable more reactions, researchers from the University of Colorado at Boulder reported last fall in the *Astrophysical Journal*.

But just getting two molecules together doesn't seal the deal. Gas-on-gas collisions can break bonds, and the molecules fall apart (the analytic technique mass spectrometry relies on this "collision-assisted dissociation"). Bonds can also form to yield a new species. But in space, molecules may be more noncommittal. Two gases can collide but, instead of bonding, form a complex in which they maintain their own identities.



Cosmic chemistry cycle Unraveling the chemical networks of space could allow researchers to use cosmic compounds as probes for understanding the evolution of stars, galaxies and planetary systems.

Chemistry on ice



If gas-on-gas isn't your thing, reactive species can also meet on the surface of — or even within — dust grains. The bits of soot and silicates that make up interstellar dust can develop mantles of ice several layers thick. The ice itself is usually frozen water, but other compounds, such as ammonia, methane and carbon dioxide may also be present. When temperatures inside a cloud plummet, gases can condense onto grains the way that ice builds

MOLECULES: A. NANDY; GRAPHIC: BILL SAXTON/ NRAO, ASSOCIATED UNIVERSITIES INC., NSF

up inside a freezer, says chemist Ralf I. Kaiser of NASA's Astrobiology Institute at the University of Hawaii at Manoa.

"In classical high school chemistry, ices have no chemistry; chemistry is dead," says Kaiser. But experiments by Kaiser and others suggest that energy from cosmic rays and from UV photons can penetrate these icy bits of dust, spurring reactions even in ice.

The mechanisms aren't clear, but scientists think that these reactions might happen when photons excite the solid material, creating tunnels through which electrons can travel to meet species locked in the ice. Or gas-phase species can land on an ice grain and connect with molecules bound to the grain's surface.

These incoming photons can also knock molecules from the ice right into the gas phase, says Louis Allamandola of the astrochemistry division of NASA-Ames. "The energy comes in, and it's like hitting something with a hammer," he says. "And the way of getting rid of some of that energy, since the grain is so small, is things pop off."

Radicals — species that are reactive because they have unpaired electrons — and ions can form and build up in the ice or can pop off and help make bigger molecules.

How much complexity arises from gas-gas collisions versus ice-grain chemistry is still hotly debated, says Herbst. Work suggests that ice is where a lot of the action begins: Radicals and positively or negatively charged ions can be liberated from these ices if the temperature goes up, say from a nearby explosion or the gradual heating of a developing star. These molecules then may also pair up, though scientists are far from unraveling this chemical network.

Modeling becomes even more complicated as temperatures rise and as the chemical population and number of reactions increase. Theory, guesswork, lab experiments and comparisons with actual measurements from space mean constant adjustments, the addition of better numbers, and reruns of experiments and models. Fully understanding the cosmic chemical landscape will be aided by other fields, including combustion and atmospheric science (which are light-years ahead of astrochemistry in both theory and experiment).

A giant step forward will come when telescopes such as ALMA, the Atacama Large Millimeter/submillimeter Array, come online. A 66-telescope array in northern Chile, ALMA should be fully functioning by 2013. These telescopes will allow scientists to probe the distribution of molecular species at greater resolutions and envision where species are in relation to each other. It's as if current technologies allowed scientists to identify lots of a molecule in Texas, while the arrays will make it possible to discern what's happening in Dallas versus Houston.

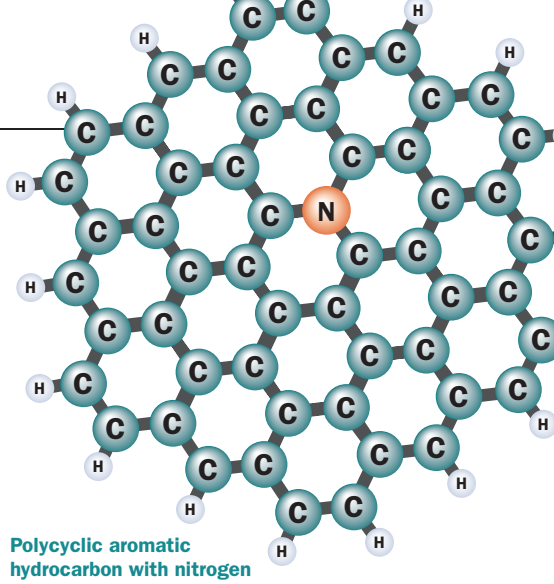
Chemists may be able to predict how molecules evolve from one cosmic environment to another.

"The real hope is that soon we'll be able to have this spatial correlation," says Pate, "where we can really say it looks like molecule A is being consumed and molecule B is being formed."

Eventually, chemists may be able to predict how molecules evolve from one cosmic environment to another. For example, species associated with ice grains can be released when a shock wave rocks the firmament. Detecting the presence of such a molecule could help isolate and locate shocks through galactic time. "You can figure out lots of things," says Herbst. "The temperature, the pressure, how fast a cloud is moving towards us or collapsing or moving away from us, or all of the above."

Lively pizzazz

Since many of these molecules get bottled in comets and meteorites and delivered to planet surfaces, understanding the cosmic chemistry set may even lead to a better understanding of the origin of life. Lab studies have generated uracil, a building block of RNA, from irradiated ices, Sandford and colleagues reported last year. In 2008, researchers found amino acetonitrile, a precursor of the simplest natural amino acid, in space.



Polycyclic aromatic hydrocarbon with nitrogen

The same ionizing radiation that gives many of space's rocked-out radicals their pizzazz may also have lent life its spark. "It gets into the whole question of electricity — now you have electrical forces instead of chemical forces," says Allamandola. "Once we've introduced electrons, I'm thinking sparks and Frankenstein." He laughs. "It's completely speculative, but it could play a role."

Whether created in space and delivered to the planet, or cobbled together somewhere on the early Earth, space's molecular species are whence we came. After all, all the carbon in the universe was created in space — we are stardust.

New techniques, telescopes and collaborations will plunge scientists into this final frontier — and challenge them to keep up with the data. When ALMA is operating, astronomers will be deluged by information. Improved lab techniques and broadband capabilities have also ramped things up.

"A year is a day now," says Pate. "It's going to force people to think differently about how you look at the data, analyze the data and extract the chemical information. I find it very exciting. When it doesn't give me a headache, it excites me." ■

Explore More

- Visit the National Radio Astronomy Observatory site: www.nrao.edu
- Learn about ongoing research at the Center for Chemistry of the Universe site: http://bit.ly/4ulBMr

A. NANDY

Communicating Science: Professional, Popular, Literary

Nicholas Russell

Books about science communication typically start from the premise that communication is important and proceed to tell scientists how to do it better. Russell's book departs from that tradition to analyze the history of such communication and look at how views of its importance have changed over time. The result is a fascinating exploration of past and current trends, with some insight into what the future may hold.

As the title denotes, the book covers science communication in three realms, beginning with information sharing among scientists themselves. Russell, a professor of science communication at Imperial College London, describes how respected journals such as *Philosophical Transactions of the Royal Society* evolved. He questions the effectiveness and fairness of peer review and looks ahead to the future role of open-access online journals in professional science communication.

Russell then parses efforts to impart scientific understanding to the public and engage the public with scientific efforts. He references primarily British programs, but the challenges he describes for popular science communication apply more broadly. In an interesting departure from the standard spiel, the book also questions what level of popular science communication is truly necessary to create informed citizens in a democracy.

The final section discusses how the literature of a culture or era reflects general attitudes toward science and scientists. Russell examines such greats as *The Time Machine*, *Dr. Jekyll and Mr. Hyde* and, of course, *Frankenstein*. Dissertations have addressed this topic, so Russell's treatment is relatively abbreviated. But the section is cogent and provides a fitting close to this interesting and important book. —*Rachel Zelkowitz*

Cambridge University Press, 2010, 324 p., $31.99.

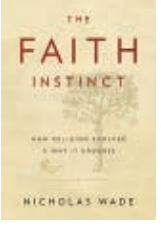
The Faith Instinct: How Religion Evolved & Why It Endures

Nicholas Wade

Several recent best sellers in the natural and social sciences have portrayed religious belief as irrational and even downright harmful. In his new book, Wade gives faith a reprieve. He argues that religion served crucial purposes in ancient societies and, via evolution, became ingrained in the human brain.

Wade offers a respectful outlook on humanity's faith in gods and supernatural powers, while not shying away from the darker side of religious convictions, including wars and inquisitions. But his notion that natural selection equipped human brains with an innate system for learning religion is speculative.

Beginning at least 50,000 years ago, bands of hunter-gatherers acted according to religious rules and rituals, Wade proposes. Religion fostered moral standards that held groups together. The societies that benefited most from the unifying power of shared beliefs outcompeted rivals and thus left more survivors, Wade writes, and so genes underlying a brain-based "faith instinct" proliferated.



Wade, a science journalist, grounds his ideas on two controversial assumptions: that natural selection acts on groups, not just individuals, and that genes can provide the basis for faith.

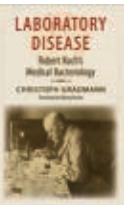
Wade's thesis will generate at least as much dispute as has the notion of a language instinct, which he also embraces. Beliefs in higher powers may get built from basic forms of interpersonal and social learning, not from a preset brain circuit, some social scientists argue. Heaven knows, some fascinating research lies ahead. —*Bruce Bower*

Penguin Press, 2009, 320 p., $25.95.

Write an Effective Funding Application: A Guide for Researchers & Scholars

Mary W. Walters

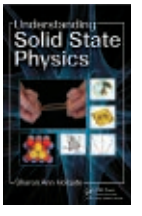
A step-by-step guide to creating successful funding proposals. *Johns Hopkins University Press, 2009, 151 p., $22.*



Laboratory Disease: Robert Koch's Medical Bacteriology

Christoph Gradmann and Elborg Forster, translator

A science historian examines the origins of the field of medical bacteriology and the life of one of its founders. *Johns Hopkins University Press, 2009, 318 p., $35.*



Understanding Solid State Physics

Sharon Ann Holgate

The authors explain basic physics principles with undergraduates in mind.

CRC Press, 2010, 349 p., $79.95.

The Nature Study Movement

Kevin C. Armitage

A scholar describes the amateur naturalists of the late 19th century and their influence on modern environmentalism. *University Press of Kansas, 2009, 291 p., $34.95.*

Turtles: The Animal Answer Guide

Whit Gibbons and Judy Greene

Turtle experts address 100 or so of the most common questions about these reptiles. *Johns Hopkins University Press, 2009, 163 p., $24.95.*

How to Order To order these books or others, visit www.sciencenews.org/bookshelf. A click on a book's title will transfer you to Amazon.com.

Thinking animals

An interesting article, but the question of human consciousness seems no closer to solution in "Humans wonder, anybody home?" by Susan Gaidos (*SN: 12/19/09, p. 22*) than it did in Julian Jaynes' *The Origin of Consciousness in the Breakdown of the Bicameral Mind* of 1976. It seems to me that all the mental abilities discussed do not show that humans can do something unique to our species, or show that we are more "conscious" than other species, but only that species display varying degrees of ability. For example, humans are not the only animals to make tools, we just make better ones.

But what I've never seen investigated (except in Jaynes' book) is the one attribute that seems uniquely human. Most animals appear interested in the answers to "What is it?" "Who is it?" "Where is it?" and even "When is it?" It also seems clear that many species are working on the question "How?" as when the crow learns to make a hook. But where is the evidence that any other species has ever asked "*Why*?"

Richard S. Blake, East Falmouth, Mass.

In the article "Humans wonder, anybody home?" the author states (Page 25): "Octopuses share one brain trait with mammals and birds: They have a high brain-to-body mass ratio."

However, considering the visual plot (Page 24) showing brain weight as a function of body weight for various species, the octopus has one of the lowest brain-to-body mass ratios of all the species shown.

Am I reading the plot incorrectly or is there a disconnect between the plot and the text in the article? If I am interpreting the plot correctly as showing that the octopus has a low brain-to-body mass ratio, why is it that "octopuses do seem to be one of the most intelligent invertebrates around"?

Jerry Kerrisk, Santa Fe, N.M.

The octopus's brain-to-body mass ratio is lower than that of most mammals shown. But "mammals" is the key word. The plot is intended to convey that the octopus brain rivals that of mammals and birds, despite the fact that the octopus is an invertebrate — a group often assumed to be less intelligent. — Elizabeth Quill

Clarification: *The article "Humans wonder, anybody home?" states that in 2005, Duke University neuroscientist Erich Jarvis showed that bird brains consist of more than a few primitive structures. Actually the research was compiled over several decades by neuroscientists Harvey Karten and R. Glenn Northcutt, both at the University of California, San Diego, and collaborators. In 2005, Jarvis organized a conference to formally revise the existing nomenclature for bird brains.*

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Charles D. Ferguson

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Energy, safety and nuclear capabilities intertwined

On January 1, Charles D. Ferguson became president of the Federation of American Scientists, a nongovernmental organization founded in 1945 by Manhattan Project scientists to promote humanitarian uses of science and technology. Ferguson worked at FAS 10 years ago as director of its nuclear policy project, and he returns after working from 2004 to 2009 at the Council on Foreign Relations as part of the Independent Task Force on U.S. Nuclear Weapons Policy. Science News *assistant managing editor Kristina Bartlett Brody asked Ferguson to discuss nuclear energy and nonproliferation.*

How does nuclear energy fit in the overall energy picture today?

To put this in somewhat stark terms, it seems that often the debate is either death by climate change or death by nuclear war. It seems that dire at times. So, we're all looking around for solutions, and there's a recognition that there's no one so-called silver bullet, but there are strong advocates who say that nuclear power must play a major role in combating climate change ... because an operating nuclear power plant does not emit greenhouse gases.... Now, people in the nonproliferation community tend to think that if we go down that path, we're going to have more and more countries with nuclear power plants and in essence latent nuclear weapons programs. Are we going to be in what [nonproliferation expert] Albert Wohlstetter warned of 30 years ago, "life in a nuclear armed crowd"?

We need a comprehensive global energy assessment. President Obama has a great opportunity. He should go back to President Eisenhower's speech from 1953, the "Atoms for Peace" speech. An update for our current times is that, instead of so much relying on nuclear energy — atoms for peace — in saving the world, instead we need to harness all energy technologies much more wisely and especially shift to greener technologies. Nuclear can be part of that, but we also need to uphold all the criteria: safety, security and nonproliferation. Certain countries can meet those criteria and others will not. And I think the United States has a great opportunity to be a provider and not a denier of technology in the energy sector.

Do countries use climate change to justify pursuing nuclear programs?

I think the two justifications for countries to embrace peaceful nuclear power are climate change and energy security. There are different definitions of what it means to have energy security. It certainly is not energy independence. Very few countries are energy independent. The reality is we're in an energy interdependent world.

But the concern is that countries may be hedging against their neighbors and other nuclear powers developing nuclear weapons programs. They hedge by building up the infrastructure to teach people about nuclear technologies, either openly or covertly. And they may never even acquire a nuclear power plant to make electricity, and still acquire the capability to make nuclear weapons. North Korea, for example, has never produced electricity with nuclear power, but they've produced enough plutonium for six to 10 or so weapons. And they use a research reactor. That's the starter kit for a nuclear bomb program for many countries.

We need to harness all energy technologies much more wisely.... Nuclear can be part of that.

What is an example of an emerging technology for detecting nuclear weapons production?

In 2005, a distinguished group of scientists wrote a report for the American Physical Society and drew attention to the need to "revitalize technical safeguards R&D" and also emphasized that nuclear program detection technologies were largely developed 10 to 20 years ago. This group called for a sustained increase in the technical safeguards R&D budget, which at that time was less than $5 million annually.

A technique that deserves further development is wide area environmental sampling in order to determine the efficacy of detecting releases of material, such as enriched uranium or fluorine, from clandestine nuclear fuel cycle facilities.

I think one of our best means of intelligence is the ongoing inspections by the International Atomic Energy Agency. The IAEA could benefit from also investing more in satellite imagery analysis, but the agency confronts significant budgetary limitations.

FAS scientists have been assessing nuclear capability at specific Iranian sites. How serious is the Iran situation?

I don't think we're anywhere near a crisis with them right now. What I mean by that is, technologically, based on what we know — and we could be caught by surprise again, that's true — but based on what we know, it looks like Iran is still at least a few years away from acquiring enough low-enriched uranium to have a serious breakout capability. ■

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