Primed for Suicide | Nobels 2012 | Quasicrystal Quest

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ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ NOVEMBER 3, 2012

Neandertal Arts & Crafts

Male DNA in Female Brains

Alien World Next Door

Tuned IN

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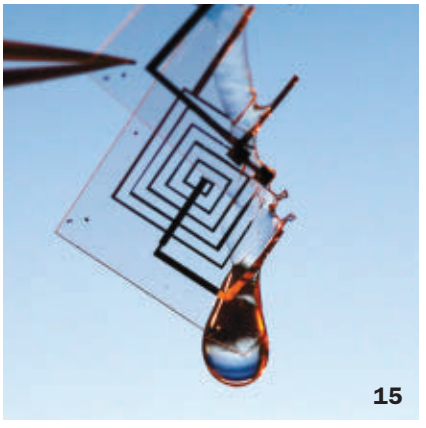
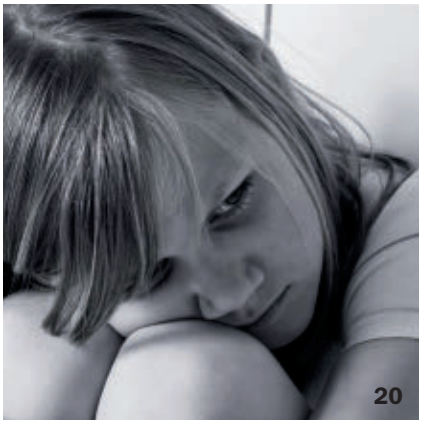
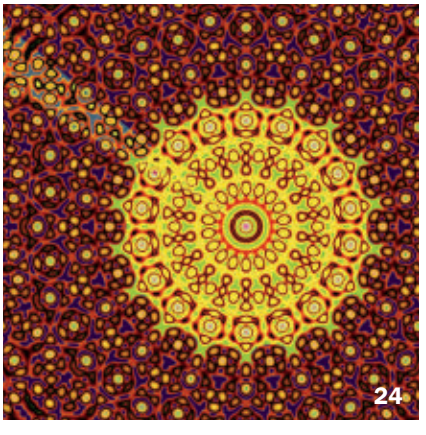
NOVEMBER 3, 2012 • VOL. 182 • NO. 9







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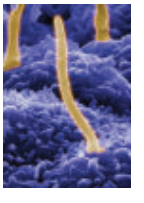
In The News

Features

Departments



COVER Cellular appendages known as primary cilia (yellow), once thought to be vestigial, turn out to play a vital role in sensing what's going on in a cell's surroundings.
William Dowdle/UCSF

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FROM THE EDITOR

Prizewinning—and prizeworthy—science

I don't envy the Nobel Prize judges. Selecting the most deserving pieces of science to honor from decades' worth of work across all of physics, chemistry and biomedicine is daunting enough. Parsing it even further to determine which individuals should get credit for what's often a group effort, or at least parallel efforts, seems even more problematic.

Even if some quibble with the exact picks—saying perhaps that this year's physics prize should have recognized theorists as well as experimentalists—the Nobels serve a grander purpose. This is one of the few times each year when scientists and scientific accomplishments are celebrated with the kind of fanfare that movie stars get all the time and shows like *American Idol* shower on unknowns.

Science News editors have an inkling of what the Nobel Prize judges go through. On a daily basis, we must decide which studies warrant attention. Covering the Nobels is a no-brainer (see Page 13). But we'd rather not wait: Over the years, many stories describing research by the 2012 winners have appeared in these pages. We have written about, for example, Serge Haroche's studies of trapped photons (*SN: 8/25/07, p. 117*) and some of David Wineland's work with atomic ions (*SN: 5/6/89, p. 279*). A 1975 story discussed new insights into cell membrane receptors, including Robert Lefkowitz's results (*SN: 8/16/75, p. 110*), and a more recent article focused on an opioid receptor study by Brian Kobilka's lab (*SN: 4/21/12, p. 12*). And a steady stream of articles has documented progress on the cloning and reprogramming of adult cells into stem cells in an embryonic-like state (*SN: 4/5/97, p. 214; 7/14/07, p. 29; 11/24/07, p. 323; 9/13/08, p. 16*) that earned John Gurdon and Shinya Yamanaka the medicine Nobel. Research by one of the economics laureates, Alvin Roth, has also appeared in this magazine (*SN: 8/25/12, p. 10*).

Science News may not be a perfect Nobel early-warning system, but it's a place where science is celebrated year-round, with gusto. In this issue, there are a number of discoveries that the Nobel committee might want to ponder: news of a new planet found just 4.4 light-years from Earth in the Alpha Centauri system (Page 5); the latest on the long-overlooked primary cilia and their surprising role in a variety of diseases (Page 16); the discovery of quasicrystals in an obscure meteorite shard (Page 24); and degradable electronics (Page 15). —*Eva Emerson, Acting Editor in Chief*

PHILIP CHANNING

Start Your Own Chain Reaction

Can the *Catalyst Necklace* make you stronger, slimmer and smarter for **ONLY $79?** Read on to find out…

This is no ordinary necklace. Wearing it immediately boosts your IQ by 45 points. It allows you to run faster, jump higher and do more one-handed push-ups than ever. Instantly converts body fat to pure muscle. In an emergency, it can be used to tow cars, fish for sharks or rappel down sheer canyon walls. Did I mention the subtle, subliminal effect it has on the ladies? It's uncanny.

Of course, none of that is true. The men's ***Catalyst Link Necklace*** won't give you actual super powers, it only feels that way. Because wearing a necklace this good-looking does things that not even science can explain. You can dismiss me as an incurable optimist. But do me a favor… wear the necklace first.

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Say What?

Soliton *SAHL-ih-tahn*\ ***n.*** A solitary wave that travels long distances without slowing down or changing shape, whether passing through Earth's atmosphere, plasma in space or fiber-optic cables. Solitons also show up in shallow ocean waters, and when two intersect (shown) they sometimes form a new wave that's taller than the sum of the individuals' heights. Called a nonlinear interaction, this special merger was thought to be rare. But researchers staking out beaches in California and Mexico report in the September *Physical Review E* that solitons frequently combine this way around low tide. The team believes similar interactions may provide a power boost to tsunamis. —*Allison Bohac*

Science Past | FROM THE ISSUE OF NOVEMBER 3, 1962

PAST-SEEKING CAMERA — A camera that can "see" what already has happened as well as what is happening may have provided the United States with information on missile

bases in Cuba.... Special photographic plates are sensitive to heat (infrared) radiation and the past presence of objects is shown differentially. This is only one of the many unique photo-devices developed for the defense of the United States. Aerial photographs taken before "quarantine" [by President Kennedy of offensive weapons entering Cuba] using a camera with telescopic lens, probably at altitudes above 60,000 feet over Cuban jungles, clearly show launching pads and intermediate range missiles obviously of an offensive military nature. See on this week's front cover a picture of a medium range ballistic missile base in Cuba.

Science Future

November 8–16
Take in nine days of science-based films during the Imagine Science Film Festival at several locations around New York City. This year's films explore the mind, brain and time. See bit.ly/SFimfilm

November 17
A new exhibit called "Our Global Kitchen" at the American Museum of Natural History in New York City explores issues around growing and eating food. More information at bit.ly/SFglobalfood

SN Online

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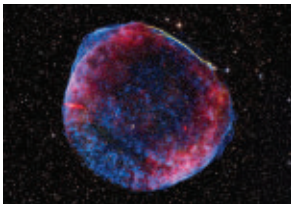
ON THE SCENE BLOG
Deep brain stimulation shows promise for treating spinal cord injuries. Read "Brain zap helps spine-damaged rats walk."

ATOM & COSMOS
Two white dwarf stars may have triggered a supernova that left bubble-shaped remains. See "No companion in supernova debris."



HUMANS
A small-scale society figures out how to put an end to years of violence. Read "In New Guinea, peace comes with a price."

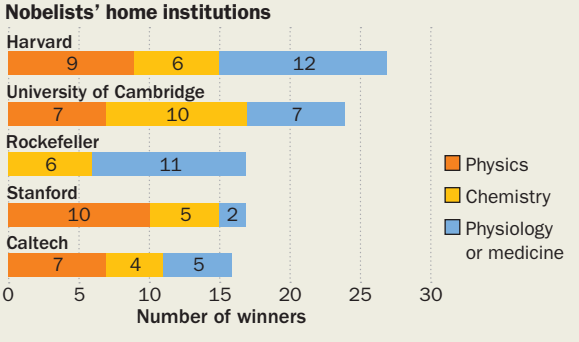
ENVIRONMENT
Poor ventilation in classrooms may affect student cognition. Learn more in "Elevated carbon dioxide may impair reasoning."

How Bizarre | SWOONING SIBLINGS

A new study of Australian twins reveals that one type of fainting can be genetic. Vasovagal syncope is the most common form of fainting, caused by a sudden drop in blood pressure in response to triggers like scary thoughts, seeing blood or standing too long. Frequent fainting of this form (three or more times in a lifetime) in both siblings was more common among identical twins than in fraternal pairs, Samuel Berkovic of the University of Melbourne in Australia and colleagues report in the Aug. 7 *Neurology*. No clear inheritance pattern was seen in the twins' extended families, suggesting multiple genes and environmental factors are at play. —*Erin Wayman*

Science Stats | WINNINGEST UNIVERSITIES

Nobel Prize winners in chemistry, physics and physiology or medicine have most often been affiliated with these universities at the time the prizes were announced. SOURCE: NOBELPRIZE.ORG



CLOCKWISE FROM TOP LEFT: COURTESY OF MARK J. ABLOWITZ; X-RAY: NASA, CXC, G. CASSAM-CHENAÏ AND J. HUGHES *ET AL*/RUTGERS UNIV.; RADIO: NRAO, AUI, NSF, GBT; K. DYER, R. MADDALENA AND T. CORNWELL/VLA, OPTICAL: F. WINKLER/MIDDLEBURY COLLEGE, NOAO, AURA, NSF, CTIO, SCHMIDT/DSS; BILLYFOTO/ISTOCKPHOTO

“If Einstein's theory is going to break down, this is where it'll happen.” —SHEP DOELEMAN, PAGE 10

In the News

STORY ONE

Earth-sized planet found in Alpha Centauri

Nearest known extrasolar world is 4.4 light-years away

By Nadia Drake

Though Earth-sized, a newly discovered planet (illustrated at right) orbiting the nearby star Alpha Centauri B lies too close to its sun to harbor life.

L. CALÇADA

Astronomers searching for Earthlike worlds need look no farther than Alpha Centauri, the stellar system next door.

An Earth-sized planet has been discovered circling a star in the system, just 4.4 light-years away. The planet's mass is similar to Earth's, but its orbit is not. Tucked in close to its star — 25 times closer than the Earth is to the sun — the planet is likely a roasted world incapable of hosting life.

Still, the discovery, reported online October 17 in *Nature*, ignites dreams of sending a spacecraft to the three-star system, a perennially favored interstellar target because of its location in Earth's celestial backyard.

“A rocky planet around Alpha Centauri, our nearest neighbor — this is incredible,” says astronomer Debra Fischer of Yale University. “If you were going to send a spacecraft anywhere, or a probe anywhere, that's where you'd go first. And if you have evidence that there are rocky planets there, you'd be insane to skip that target.”

The rocky planet circles Alpha Centauri B, a star just a bit smaller and dimmer than the sun. But the planet isn't Earth's twin: A year there lasts just 3.236 days. Being snuggled so close to the star means that the planet has a surface temperature of around 1,200 degrees Celsius, notes astronomer Greg Laughlin of the University of California, Santa Cruz. “It's utterly uninhabitable, utterly scorched, utterly un-Earthlike in every respect,” he says.

But a rocky planet so close to Alpha Centauri B suggests there could be more planets in the same system — perhaps rocky and a bit farther out, in the area where life could comfortably thrive. “I think that the odds that there's an interesting planet, a truly interesting planet in the system, are very high, given that this one is there,” Laughlin says. Data returned from NASA's Kepler spacecraft — which looks for planets around a population of stars that mostly lie more than 600 light-years away — suggest that multiple-planet systems are common, especially when small, rocky planets are found in close orbits.

There's a good chance that Alpha Centauri A — the bigger, binary partner of Alpha Centauri B — also hosts planets. But because Alpha Centauri A is bigger, brighter and more rambunctious, any small planets orbiting it would be harder to find.

Previous observations indicate that there are no planets more massive than Neptune hovering around any of Alpha Centauri's three stars. But those observations don't rule out smaller, harder-to-detect planets.

“The way we describe it is, the easy planets were all found a long time ago,” says Sara Seager, an astrophysicist at MIT.

Led by a team at the University of

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Geneva, astronomers detected this planet using HARPS, the High Accuracy Radial Velocity Planet Searcher. They weren't surprised to find it.

"We know now that these planets are everywhere. The question is, how big, how far from the star? That's what we are trying to characterize," says astronomer and study coauthor Stéphane Udry of the University of Geneva. "That will help us understand how they form."

Installed on the 3.6-meter telescope at the European Southern Observatory in La Silla, Chile, HARPS looks for stars being gravitationally tugged by orbiting planets. Because this planet is so small, its gentle tugs pull only very slightly on Alpha Centauri B, shifting the star's position by about 50 centimeters each second. So finding the planet's signature in the star's wobbles meant the team needed to carefully filter out other sources of stellar variability such as star spots, bulges on the star's surface and gravitational interactions with Alpha Centauri A.

"It's a tough detection; there's absolutely no question about it," Fischer says. "A detection that's as technically difficult as this one requires confirmation."

Fischer is planning to conduct follow-up observations with an instrument called CHIRON, which analyzes stellar wobbles in a slightly different way.

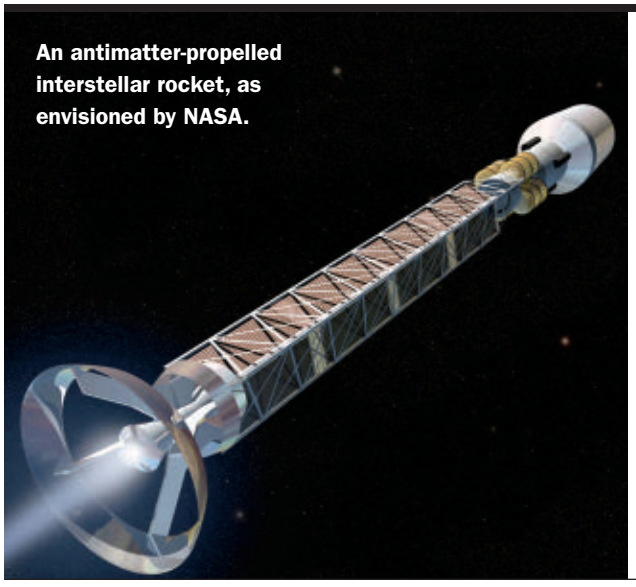
Astronomers found an Earth-sized planet in the Alpha Centauri system using a custom-built instrument on the 3.6-meter telescope at the European Southern Observatory (shown) in the Chilean Andes.

There's also a chance — at least 10 percent but perhaps as high as 25 percent, Laughlin says — that the planet passes between Alpha Centauri B and Earth. If so, astronomers could watch for dips in starlight produced as the planet crosses their line of sight to the star.

That's the same method the Kepler spacecraft uses to find planets — but Kepler isn't pointed anywhere near Alpha Centauri, so it can't do the job. Another orbiting telescope, Canada's MOST microsatellite, might be able to detect the planet's dark fingerprint and determine its radius, allowing scientists to calculate its density and probable ingredients.

Though the planet isn't a true Earth analog, it pegs Alpha Centauri as a legitimate destination for a spacefaring probe to an extrasolar world — albeit one on the fringes of practicality. Even a cell phone–sized space probe accelerated to 10 percent the speed of light would be in transit for 40 years. It would also have to be capable of managing extreme temperature variations, remaining functional for decades, communicating with Earth from light-years away and orbiting a small planet close to its sun without becoming a stellar snack.

If scientists did find a way to spy on the planet, what would they do? Take photos. "You could imagine just zooming by and snapping a picture. Like Voyager," Seager says. Study the planet's atmosphere — if it has one — and its innards. Try to drop probes onto it — probes that wouldn't melt. Or, if the planet is locked in orbit with one side always facing the star, "you could land on the dark side, where it would be a lot cooler," Seager says. "It opens up our imaginations, trying to think of how we're going to get there." ■



An antimatter-propelled interstellar rocket, as envisioned by NASA.

Back Story | HALF THE FUN

With current technologies, even Mars takes eight months to reach. But Les Johnson of the Advanced Concepts Office at NASA's Marshall Space Flight Center in Huntsville, Ala., says there are several potential future technologies that could propel a spacecraft to Alpha Centauri within centuries. Among the possibilities:

- **Matter-antimatter annihilation:** "You would need on the order of hundreds, if not thousands, of kilograms" of antimatter.
- **Nuclear fusion:** "As soon as we figure out how to get more [energy] out than we put in, then you might be able to do it."
- **Solar sails:** You'd need "a sail that's about as big as Texas in surface area, weighing just a fraction of a gram per square meter."
- **Explosive nuclear propulsion:** "This is a really awful idea, but it probably would work."

FROM TOP: DAVID NUNUK/SCIENCE SOURCE/PHOTO RESEARCHERS, INC.; NASA

Chicago Doctor Invents Affordable Hearing Aid

Outperforms Many Higher Priced Hearing Aids

Reported by J. Page

CHICAGO: A local board-certified Ear, Nose, Throat (ENT) physician, Dr. S. Cherukuri, has just shaken up the hearing aid industry with the invention of a medical-grade, affordable hearing aid. **This revolutionary hearing aid is designed to help millions of people with hearing loss who cannot afford—or do not wish to pay—the much higher cost of traditional hearing aids.**

"Perhaps the best quality-to-price ratio in the hearing aid industry" – Dr. Babu, M.D. Board Certified ENT Physician

Dr. Cherukuri knew that untreated hearing loss could lead to depression, social isolation, anxiety, and symptoms consistent with Alzheimer's dementia. **He could not understand why the cost for hearing aids was so high when the prices on so many consumer electronics like TVs, DVD players, cell phones and digital cameras had fallen.**

Since Medicare and most private insurance do not cover the costs of hearing aids, which traditionally run between $2000-$6000 for a pair, many of the doctor's patients could not afford the expense. Dr. Cherukuri's goal was to find a reasonable solution that would help with the most common types of hearing loss at an affordable price, not unlike the **"one-size-fits-most" reading glasses** available at drug stores.

He evaluated numerous hearing devices and sound amplifiers, including those seen on television. Without fail, almost all of these were found to amplify bass/low frequencies (below 1000 Hz) and not useful in amplifying the frequencies related to the human voice.

Inspiration from a surprising source

The doctor's inspiration to defeat the powers-that-be that kept inexpensive hearing aids out of the hands of the public actually came from a new cell phone he had just purchased. **"I felt that if someone could devise an affordable device like an iPhone® for about $200 that could do all sorts of things, I could create a hearing aid at a similar price."**

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Affordable Hearing Aid With Superb Performance

The high cost of hearing aids is a result of layers of middlemen and expensive unneccesary features. Dr. Cherukuri concluded that it would be possible to develop a medical grade hearing aid without sacrificing the quality of components. The result is the MDHearingAid PRO®, starting well under $200. **It has been declared to be the best low-cost hearing aid that amplifies the range of sounds associated with the human voice without overly amplifying background noise.**

Tested By Leading Doctors and Audiologists

The MDHearingAid PRO® has been rigorously tested by leading ENT physicians and audiologists who have unanimously agreed that the **sound quality and output in many cases exceeds more expensive hearing aids.**

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"I have been wearing hearing aids for over 25 years and these are the best behind-the-ear aids I have tried. ***Their sound quality rivals that of my $3,000 custom pair of Phonak Xtra digital ITE"*** —Gerald Levy

"I have a $2,000 Resound Live hearing aid in my left ear and the MDHearingAid PRO® in the right ear. ***I am not able to notice a significant difference in sound quality between the two hearing aids."*** — Dr. May, ENT Physician

"We ordered two hearing aids for my mother on Sunday, and the following Wednesday they were in our mailbox! Unbelievable! Now for the best part—they work so great, my mother says she hasn't heard so good for many years, even with her $2,000 digital! ***It was so great to see the joy on her face.*** *She is 90 years young again."* —Al Peterson

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Humans

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Human-Neandertal matings dated

Cross-species liaisons happened in later Stone Age

By Bruce Bower

A new study suggests that present-day Europeans share more genes with now-extinct Neandertals than do living Africans, at least partly because of interbreeding that took place sometime between 37,000 and 86,000 years ago.

Cross-species mating occurred when Stone Age humans left Africa and encountered Neandertals, or possibly a close Neandertal relative, upon reaching the Middle East and Europe in the latter part of the Stone Age, says a team led by geneticist Sriram Sankararaman of Harvard Medical School.

The new study, published online October 4 in *PLOS Genetics*, indicates that at least some interbreeding must have occurred between *Homo sapiens* and Neandertals, Sankararaman says. But it's not yet possible to estimate how much of the Neandertal DNA found in modern humans comes from that interbreeding and how much derives from ancient African hominid populations ancestral to both groups.

Mating between European Neandertals and modern humans most likely occurred between 47,000 and 65,000 years ago.

A separate analysis of gene variants in Neandertals and in people from different parts of the world also found signs of Stone Age interbreeding outside Africa. That study, published in the October *Molecular Biology and Evolution*, was led by evolutionary geneticist Melinda Yang of the University of California, Berkeley.

Results from Sankararaman's and Yang's groups "convincingly show that the finding of a higher proportion of Neandertal DNA in non-Africans compared to Africans can be best explained by gene flow from Neandertals into modern humans," says evolutionary geneticist Johannes Krause of the University of Tübingen in Germany.

Other studies have found that ancient interbreeding may not be necessary to explain the presence of Neandertal DNA in modern humans. It may be possible that African populations ancestral to both *H. sapiens* and Neandertals possessed some genes that became part of the genomes of both species.

Sankararaman and his colleagues measured the lengths of DNA segments shared by Neandertals and present-day Europeans. Since genetic reshuffling via sexual reproduction reduces the size of such segments over time, lengths of Neandertal-related chunks of DNA in people today can be used to calculate the time since those chunks entered the human genome.

The researchers say that mating between European Neandertals and modern humans most likely occurred between 47,000 and 65,000 years ago.

Feathers hint at Neandertal art

Extinct human relatives may have had abstract thoughts

By Bruce Bower

Neandertals may not have painted pictures on cave walls, but a new study proposes they had an artistic sensibility. These close Stone Age relatives of people regularly made personal and possibly ritual ornaments that included bird feathers.

Neandertals took a fancy to feathers on their own, several thousand years before encountering Stone Age people who also adorned themselves with plumage, the researchers contend in a paper published online September 17 in *PLOS ONE*. That suggests big-boned, slope-faced Neandertals shared with ancient humans a mental talent for using concrete objects — whether rock drawings or decorative feathers — to represent abstract ideas and beliefs, say evolutionary ecologist Clive Finlayson of the Gibraltar Museum and his colleagues.

That conclusion is questionable, and the new study won't resolve a long-standing scientific debate about whether Neandertals' mental faculties matched those of *Homo sapiens*, remarks anthropologist Mary Stiner of the University of Arizona in Tucson. "It's difficult on the basis of the information presented to float the claim that birds were a central and widespread prop in Neandertal ritual," Stiner says.

Finlayson's team first analyzed remains from 1,699 Stone Age sites, mostly caves, in North Africa, Asia and Europe that have yielded bird fossils. Bones of large birds have often been found mixed with Neandertal fossils at sites dating to between roughly 100,000 and 28,000 years ago.

Examination of 604 bones from 21 bird species, most previously excavated at Gorham's Cave, a Neandertal site in Gibraltar, revealed a predominance of wing fossils. Remains of at least 18 birds displayed stone-tool incisions or breaks produced during feather removal, the researchers say.

Neandertals used bird feathers throughout their time at Gorham's Cave, which lasted from at least 42,000 years ago to 28,000 years ago (*SN Online: 9/22/08*), Finlayson and his colleagues propose.

Life

216 million Cases of human malaria infection, 2010

655 thousand Human deaths caused by malaria, 2010

Birds catching malaria in Alaska

Disease may move north of Arctic Circle within decades

By Susan Milius

Birds can catch malaria at least as far north as Fairbanks, Alaska, a new study confirms. And at the rate climate is expected to change, the risk zone for avian malaria might stretch within the Arctic Circle by 2080.

Throughout much of continental North America, malaria-causing *Plasmodium* parasites have been using mosquitoes to hitchhike from bird to bird for eons. But many long-exposed bird species don't get particularly sick because they've developed some degree of tolerance over time. What's worrisome about the northward creep of malaria risk is that parasites might reach bird populations that haven't been exposed, explains disease ecologist Ravinder Sehgal of San Francisco State University.

People aren't at risk: The 80-plus species of *Plasmodium* that cause avian malaria don't infect humans, nor do the five that cause human malaria affect birds. Shifting climate may also change transmission risk for the human form of the disease, but with its own pattern.

Genuine made-in-Alaska malaria transmission showed up in several Fairbanks birds, Sehgal and his colleagues report September 19 in *PLOS ONE*. The researchers could tell that the parasites had attacked locally because one bird, an infected myrtle warbler, was too young to have migrated yet and the remainder, all black-capped chickadees, stay in Alaska year-round.

Previous studies in the region hadn't distinguished between local transmission and infections picked up elsewhere. So the new paper gives the first evidence of avian malarial transmission in the upper reaches of North America, Sehgal says.

What that shift might do to bird populations will depend on the bird species, says conservation geneticist Robert Fleischer of the Smithsonian Institution's Center for Conservation and Evolutionary Genetics in Washington, D.C. A species of malarial parasite that had appeared relatively benign elsewhere in the world has swept into Hawaii. Some birds cope, but in others the parasite is "very virulent and deadly," he says. Now some of the native birds can survive only high in the safety of mountain slopes, where it's too chilly for the parasite-carrying mosquitoes to thrive.

Rising temperatures may already be pushing avian malaria upslope in Hawaii, says Carter T. Atkinson of the U.S. Geological Survey's Kilauea Field Station in Hawaii Volcanoes National Park. On the island of Kauai, transmission has shifted to higher elevations as temperatures have increased.

The disease may expand its reach in Alaska too, Sehgal and colleagues say. Their simulations suggest that temperatures and rainfall levels suitable for avian malarial transmission could occur north of the Arctic Circle by 2080.

There's also the other end of the Earth to worry about: Sehgal frets that as the Antarctic warms, penguins may have to cope with malaria. ■

How dino teeth got their groove

Duck-billed dinosaurs were the Cuisinarts of the Late Cretaceous period, pulverizing tough, gritty plants such as conifer trees using hundreds of rough, interlocking teeth (shown). Now, scientists have figured out how the herbivores developed their complex chompers: The animals' teeth contained six types of tissue that wore down to differing degrees, creating distinctive peaks and valleys. The surface of the duck-billed dinos' teeth resembles that of horses and other modern grazers that have four main types of tooth tissue. Gregory Erickson, a paleobiologist at Florida State University, and colleagues studied nearly 70-million-year-old *Edmontosaurus* teeth and found two additional dental tissues, the researchers report in the Oct. 5 *Science*. Computer simulations demonstrated how the varying hardness of the tissues would allow different dental features to form as a tooth wore down. — *Erin Wayman*

G. M. ERICKSON *ET AL*./*SCIENCE* 2012

Atom & Cosmos

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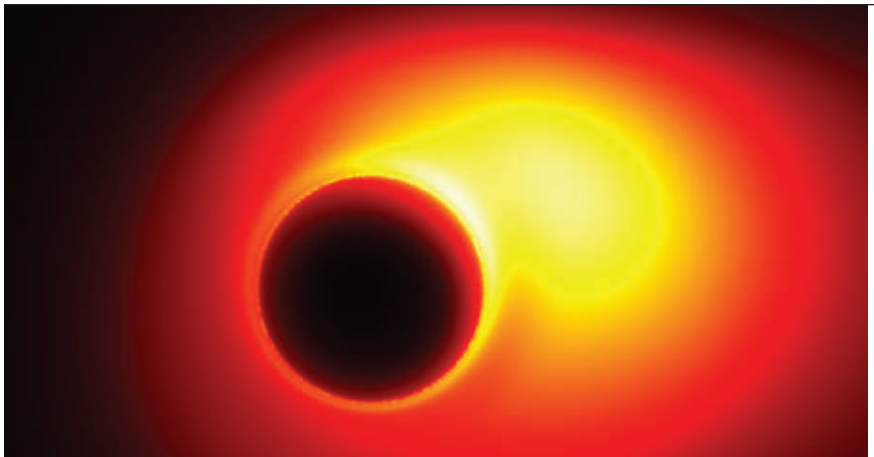

Black hole's veil peeled back to reveal bases of powerful jets

Peek at M87 shows promise of new telescope network

An artist's representation shows a jet (yellow) launched by the supermassive black hole at the center of galaxy M87. The black hole shadow is depicted as circular, as predicted by Einstein.

By Nadia Drake

A network of radio telescopes has produced the most detailed observations yet of a supermassive black hole in one distant galaxy's churning heart. The observations, reported online September 27 in *Science*, may help explain how some active galactic nuclei launch powerful plasma jets thousands of light-years into space.

"This is a tremendous technical achievement," Stanford University astrophysicist Roger Blandford says of the new observations. "It's a step along the road to an ambitious goal of imaging a black hole in a galactic nucleus."

When complete, the Event Horizon Telescope network will focus on the black holes that power galaxies, cosmic engines so extreme that they could test Einstein's theory of general relativity. In 2009, astronomers aimed the partially complete radio telescope array at M87, located 53.5 million light-years away in the constellation Virgo. The bright, supergiant elliptical galaxy has a black hole weighing more than 6 billion suns.

Because it's so huge, the black hole is pulling in enormous quantities of gas and dust. The extremely hot, opaque material spiraling in obscures the cosmic drain to all but specific radio wavelengths, which can pierce through the maelstrom and see the structures driving the chaos.

M87 produces two enormous plasma jets, streams of charged particles traveling at nearly the speed of light and extending more than 5,000 light-years from the black hole's poles. Roughly 10 percent of active galactic nuclei emit such jets. Until now, scientists hadn't been able to see the source of these jets and puzzled over their engines.

Over 36 hours in April 2009, researchers pointed four radio telescopes at the veiled heart of M87, observing and measuring the base of an enormous jet erupting from the galaxy's core.

To the astronomers' surprise, the jet base was narrow enough to almost be a physical impossibility — unless the black hole was spinning at roughly 65 percent the speed of light. Such an interpretation points toward an answer to the still-open question of whether a spinning black hole is required to launch such jets.

"They had to make a couple of assumptions. One is that they're looking at the base of the jet. They probably are," says astrophysicist Alan Marscher of Boston University.

M87's jets are formed from particles that are swept up as they approach the black hole and launched outward, saving them from being crunched into nothingness. In these extreme environments, magnetic fields coming from the matter spiraling inward can act like rubber slingshots. They twist around the jet, squeezing the particle stream and focusing and accelerating it.

The new study suggests that the M87 jet is powered by an area very close to the black hole itself, and not by an engine farther out in the debris disk.

"It doesn't prove that the power is extracted directly from the black hole, but it's certainly consistent with that," says Blandford, who developed early theories describing black hole–powered jets.

The findings also match observations published this year in *Astrophysical Journal Letters* that suggest the M87 jet base is extremely narrow. "Their conclusions are quite within our previous expectations," says Masanori Nakamura, an astrophysicist at Taiwan's Academia Sinica Institute of Astronomy and Astrophysics, who studies M87.

Because a behemoth black hole's surroundings are dominated by extreme gravitational forces, scientists are hoping to use the Event Horizon Telescope to test Einstein's theory of general relativity. "If Einstein's theory is going to break down, this is where it'll happen," says coauthor Shep Doeleman of MIT's Haystack Observatory in Westford, Mass. Doeleman's team hopes within the next few years to verify whether spacetime curving around a black hole produces a dark, circular disk surrounded by a ring of photons. So far, Doeleman says, Einstein's calculations are holding up well. "It's never a good idea to bet against Einstein." ■

COURTESY OF AVERY E. BRODERICK/UNIV. OF WATERLOO AND PERIMETER INSTITUTE FOR THEORETICAL PHYSICS

"A black hole is, almost by definition, the breakdown of Einstein's general relativity." —ANDREA GHEZ

Superfast star orbits galaxy center

Close encounter with black hole can test general relativity

By Nadia Drake

If Usain Bolt were a star — of the astronomical type — he'd be S0-102, which sprints around the Milky Way's central black hole with the fastest time yet. It takes just 11.5 years for S0-102 to orbit the supermassive cosmic drain, astronomers report in the Oct. 5 *Science*.

Not to worry—"it's not in danger of being sucked in," says astrophysicist and study coauthor Andrea Ghez of UCLA. "But it is getting close enough that in principle, we can see the impact of the curvature of spacetime on its orbit."

Spotted using one of the Keck telescopes in Hawaii, S0-102 dethrones another stellar sprinter called S0-2, which takes a comparatively pokey 16 years to orbit the black hole. For nearly two decades, Ghez and her colleagues have been searching for stars moving oddly in this region — first, as proof the black hole exists, and now, as tools to test Einstein's theory of general relativity, which may not hold up in a supermassive black hole's immediate neighborhood.

There's no doubt the team's observations are accurate — and impressive, says astronomer Stefan Gillessen of the Max Planck Institute for Extraterrestrial Physics in Garching, Germany. Gillessen and his colleagues also observe the galactic center, which he says is a very confused and chaotic environment.

Scientists will keep a close eye on the daredevil pair and plan to make some crucial observations in 2018, when S0-2 is nearest the black hole. (S0-102's closest approach is in 2021.)

As the stars near the black hole, astronomers will watch the light for any changes caused by spacetime curving around the black hole. To an observer on Earth, light escaping the extreme gravity will change its wavelength and appear to shift. The stars' paths may also wobble a bit.

"We know Einstein's theory breaks down when you get to the core, to the center of a black hole — the singularity," says Ghez. "A black hole is, almost by definition, the breakdown of Einstein's general relativity."

What scientists don't know is how close to a black hole one can get before the theory begins to disintegrate.

But it's clear living near a black hole is not an environment that every star could tolerate, Ghez says. "You've gotta be a tough little dude." ■

Body & Brain

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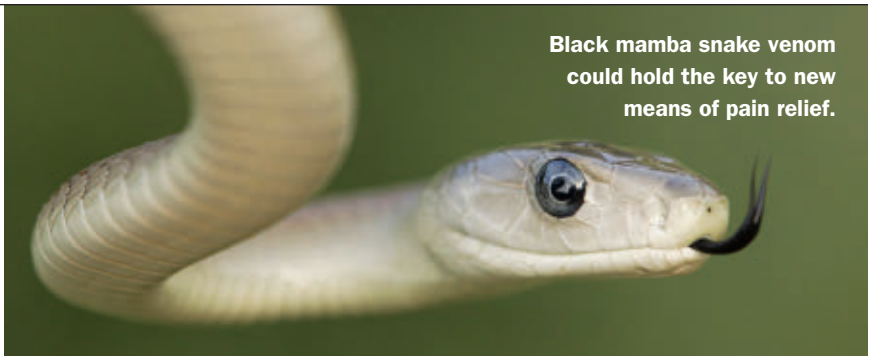
Snakebite packs potent painkiller

Venom reveals potential new strategy for relieving agony

By Tanya Lewis



Black mamba snake venom could hold the key to new means of pain relief.

A snakebite may bring on a world of hurt, but a substance found in black mamba venom could actually relieve pain. The finding reveals a new possible approach for pain treatment, researchers report online October 3 in *Nature*.

The black mamba, *Dendroaspis polylepis polylepis*, is one of the most lethal snakes on Earth. But a team of researchers in France found that compounds in the snake's venom have the same pain-banishing effect on mice that morphine does.

The compounds, called mambalgins, appear to work by blocking certain channels in nerve cells. Under acidic conditions, these channels open up, triggering pain signals. By preventing the flow of charged atoms through these channels, the mambalgins stop pain signals in their tracks.

The work highlights such acid-sensing channels as a potential target for pain treatment, says neuroscientist Candice Askwith of Ohio State University, who was not involved in the study. Morphine and other opioids work well, she says, "but they do have limitations and they do have side effects. So having an alternative chemical or pathway that could be manipulated would be a great advantage clinically."

Eric Lingueglia of the Institute of Molecular and Cellular Pharmacology in Valbonne, France, and his colleagues injected mice with either mambalgin or morphine before exposing the animals to hot water or after injecting them with chemicals designed to cause painful inflammation. In most of the tests, the venom treatment soothed pain as well as morphine did but without the side effects.

While the snake venom painkiller worked like a charm in mice, its effectiveness in humans has yet to be shown. Although the research focused on acute inflammatory and thermal pain, Lingueglia says future studies will explore its effect on other types, such as neuropathic pain, which can be very difficult to treat.

"We are just at the beginning of the story," says Lingueglia, but "the pain pathways are pretty well comparable in mice and humans, so we expect that this will also be effective in humans."

Male DNA found in female brains

Fetal cells may be able to slip through blood-brain barrier

By Laura Sanders

Children live on in their mothers' brains for decades, and not just as memories. Scientists have found pockets of male DNA, presumably from boy fetuses, in the brain tissue of deceased elderly women.

Not only is male DNA present in women's brains, it's common, researchers report online September 26 in *PLOS ONE*. J. Lee Nelson of the Fred Hutchinson Cancer Research Center in Seattle and her colleagues found snippets of a male-only gene in the brains of 18 of 26 women who died without neurological disease. The male DNA was spread throughout their brains.

The technique used in the study couldn't distinguish if the DNA was from intact, functional brain cells, though in a separate test of brain tissue from a different woman, Nelson and colleagues did spot nuclei from male cells in the brain. Earlier studies in mice hinted that these foreign cells can integrate themselves into the brain and start functioning as nerve cells.

So far, cells from fetuses have turned up in women's blood, livers, lungs, heart and other organs, so finding male DNA in the brain isn't a complete shock, says geneticist Kirby Johnson of Tufts University in Boston, who wasn't involved in the study. What's interesting is how the DNA could have gotten there. Male cells from a fetus could have broken through the blood-brain barrier — a wall that protects the fragile brain from pathogens in the blood. But that shouldn't be possible, Johnson says.

Complete medical records weren't available for the women in the study, so the researchers couldn't rule out other sources of cellular mingling. The male DNA could have come from a boy twin whose cells ended up moving into his sister's body during gestation, for instance, or through an organ donation or blood transfusion, or even an older brother who had previously occupied the same uterus as the woman.

STU PORTER/SHUTTERSTOCK

Science & Society

For longer stories on the 2012 Nobel Prizes, visit **www.sciencenews.org/nobels2012**

Probes of quantum world, cell fate, molecular messages win Nobels

Science prizes recognize studies of nature's essence

In choosing the 2012 winners of the world's most prestigious scientific honors, the Nobel Prize committees focused on fundamentals: This year's awards went to researchers who explored nature at the most basic levels.

The physics award went to a pair of researchers who developed ways to trap and examine individual particles of matter or light. The chemistry prize recognized the discovery and characterization of a type of molecule that is central to countless interactions between cells and their environment, from the fight-or-flight response triggered by adrenaline to the detection of light in the eye. And the Nobel in physiology or medicine went to researchers who showed that an adult cell's identity can be erased, leaving behind a blank slate capable of developing into any number of specialized forms.

John Gurdon of the University of Cambridge in England and Shinya Yamanaka of Kyoto University in Japan won the physiology or medicine prize for showing that cells once thought to be locked into a specific identity can revert to the extremely flexible state they had as components of a developing embryo. Gurdon's work, published in 1962, showed that transplanting the nucleus from a tadpole intestinal cell into an egg that had had its own nucleus removed could produce another tadpole.

The experiment was intended to show that DNA contains all the information needed to make an organism. Decades later, the same basic approach was used to clone sheep and other animals.

"You wait awhile — sometimes a long while — and it then turns out that all discoveries of a basic scientific nature will turn out to have some kind of useful consequence," Gurdon said.

Yamanaka's research had a more immediate impact. He changed the ethical debate over stem cell research by creating induced pluripotent stem cells, which are like embryonic stem cells in their ability to become any cell in the body but do not require destroying embryos. His technique enabled him to make embryonic-like cells from adult human cells instead.

Reprogrammed human cells have not yet been used clinically, but researchers hope they will one day be a source of replacement cells and tissues for patients.

Medicine already gets plenty of use out of the biochemical apparatus that won the 2012 chemistry Nobel for Robert Lefkowitz of Duke University and Brian Kobilka of Stanford. By some estimates, G-protein–coupled receptors are the target of up to half of all drugs on the market, including antihistamines, some psychiatric medications and beta-blockers.

The receptors are molecules that sit on the surfaces of cells and interact with hormones, odor molecules and other chemicals, passing information about them to the cell's interior. Lefkowitz first discovered them while trying to figure out how adrenaline works; follow-up research with Kobilka showed how ubiquitous G-protein–coupled receptors are and revealed how they function.

"It's like discovering the phone system of the United States if you didn't know the phone system existed," said Jack Dixon, vice president and chief scientific officer of the Howard Hughes Medical Institute, which supports Lefkowitz's research.

A revelation of hidden worlds also led to the awarding of the 2012 physics prize, which went to two researchers who use different approaches to study the quantum behavior of single particles. Serge Haroche of the École Normale Supérieure in Paris bounces light particles between mirrors to probe their quantum states; David Wineland of the National Institute of Standards and Technology in Boulder, Colo., traps charged atoms and controls them with lasers.

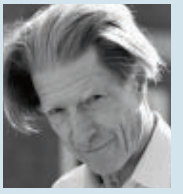
Both approaches contribute to progress toward quantum computers, which are a long way from reality but could one day be a far faster and more secure method for certain types of computing.

"These are two great experimentalists, and I'm really glad they won," said Robert Garisto, a physicist and editor at the journal *Physical Review Letters*.

— Tina Hesman Saey and Alexandra Witze

2012 NOBEL LAUREATES

Physiology or medicine



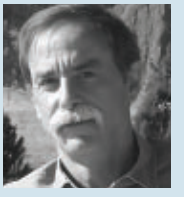
John Gurdon

Shinya Yamanaka

"For the discovery that mature cells can be reprogrammed to become pluripotent"

Physics

Serge Haroche



David Wineland

"For groundbreaking experimental methods that enable measuring and manipulation of individual quantum systems"

Chemistry

Brian Kobilka

Robert Lefkowitz

"For studies of G-protein–coupled receptors"

TOP ROW: JOHN OVERTON/BROWN GROUP, GURDON INSTITUTE; CHRIS GOODFELLOW/GLADSTONE INSTITUTES; MIDDLE ROW: © CNRS PHOTOTHÈQUE/CHRISTOPHE LEBEDINSKY; © NIST; BOTTOM ROW: LINDA A. CICERO/STANFORD NEWS SERVICE; STEWART WALLER/PR NEWSWIRE; © HHMI

Genes & Cells

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Microbes pluck out phosphorus

How 'arsenic life' bacteria avoid being poisoned

By Alexandra Witze

Hardy bacteria that live in an arsenic bath survive in part by keeping poison from entering their cells, scientists have found. Just one tiny tweak in a hydrogen bond is enough to let the microbes pick out the phosphate they need to build their DNA — while keeping arsenic out.

The work helps explain how famous bacteria in the arsenic-rich waters of Mono Lake, Calif., manage to live there without incorporating the toxic arsenic into their DNA, as a controversial 2010 paper had claimed (*SN: 2/25/12, p. 10*).

"It goes to show that life will find a way," says Matthew Pasek, a geochemist at the University of South Florida.

The discovery may also open new ways to deliver substances into a cell that are wanted, like drugs, while keeping unwanted stuff out. "The best way of avoiding poison is not to take it, and this is like the first defense mechanism," says Mikael Elias, a biochemist at the Weizmann Institute of Science in Rehovot, Israel. He and his colleagues describe the finding online October 3 in *Nature*.

Mono Lake contains a witch's brew of chemicals, yet a strain of *Halomonas* bacteria manages to thrive there. The original "arsenic life" paper contended that the strain took up arsenate (a combination of arsenic and oxygen) in place of phosphate, the structurally similar chemical that forms the backbone of DNA in living organisms.

Elias suspected that *Halomonas* somehow fishes out the tiny bits of phosphate available from a sea of arsenate. So he and his colleagues examined the structures of five proteins, including two from the Mono Lake strain of *Halomonas*, that pull phosphate from the environment into cells.

All the proteins contain a particular hydrogen bond that latches onto phosphate (and arsenate). But structurally, that bond is slightly different in one of the *Halomonas* proteins. "It's really a tiny difference, but it has a big consequence," says Elias. "Basically with phosphate this bond is almost perfect" — but with the slightly larger arsenate the bond is much harder to make. That difference lets *Halomonas* take up phosphate molecules about 4,500 times as efficiently as it takes up arsenate, the team found.

Mouse stem cells yield viable eggs

Method leads to births, may spur human fertility advances

By Tina Hesman Saey

Some baby mice born in Japan are living proof that mouse stem cells taken from embryos or created by reprogramming fetal tissue can be used to make viable egg cells.

Researchers had already created functional sperm from stem cells, and some groups have reported making eggs, or oocytes, but those had never been shown to produce offspring. Now, Mitinori Saitou of Kyoto University in Japan and colleagues have coaxed mouse stem cells to make eggs that produce normal, fertile offspring, the researchers report online October 4 in *Science*.

"This is really pioneering research," says Charles Easley, a reproductive stem cell biologist at Emory University School of Medicine in Atlanta.

David Albertini, a reproductive scientist at the University of Kansas Medical Center in Kansas City, doesn't think the feat will be repeated with human stem cells because they are far less flexible than their mouse counterparts. The new technology might provide a way to test the effect that chemicals in the environment may have on fertility and give scientists new information about how eggs age, which could possibly lead to fertility-extending treatments, he says.

In the new study, Saitou and his colleagues started with stem cells from very early mouse embryos as well as stem cells reprogrammed from fetal cells, known as induced pluripotent stem cells (see Page 13). Saitou's team manipulated the activity of a few genes in the stem cells to turn them into cells that resemble precursors of gametes, as eggs and sperm are known.

These primordial germ cell–like cells, as they are called, were mixed with support cells from an embryonic ovary and then transplanted into adult mice. Once the precursor cells had developed into oocytes, the researchers pulled the cells out and fertilized them in the lab before implanting the resulting embryos in female mice.

The oocytes made from embryonic stem cells produced mouse pups 3.9 percent of the time. Oocytes from reprogrammed stem cells did better, resulting in pups 8.6 percent of the time. Those rates are lower than for primordial germ cells taken directly from mouse embryos, which the researchers found produced pups 17.3 percent of the time. Female pups resulting from stem cell–derived eggs grew up to become fertile adults, the researchers report.

The same technique may not be applicable to generating human oocytes: The support cells used in the study were isolated from mouse embryos equivalent to 10- to 14-week-old human fetuses. "If it is dependent on fetal ovaries, that makes it completely impractical for human use," says Harvard's Jonathan Tilly.

Technology

Electronic devices vanish after use

Technique makes degradable gadgets that melt away

By Rachel Ehrenberg

Imagine your old phone dissolving away after you've traded up, or a pacemaker that's absorbed by the body when it's no longer needed. Such gadgetry may not be far off: Scientists have developed a technique for making electronic devices that disappear without a trace. Constructed of silicon, magnesium and silk, the transient electronics can be tuned to last for days, weeks or even a year — and then disappear.

Scientists used the approach to make a bacteria-fighting medical implant that melts away after a few weeks, and a simple 64-pixel sensor array like those found in digital cameras that was designed to last for about a day. The researchers also made degradable temperature and strain sensors, solar cells, transistors, radio antennas and wireless power coils. The team describes the work in the Sept. 28 *Science*.

"This is a huge step. It is a pinnacle," says materials engineer Mihai Irimia-Vladu of Johannes Kepler University in Austria. "It's a very elegant demonstration of making functional devices that are biodegradable."

BECKMAN INST., UNIV. OF ILLINOIS, TUFTS UNIV.

A biodegradable circuit dissolves in water. Such circuits could be used in medical implants, environmental sensors and other devices designed to disintegrate over time.

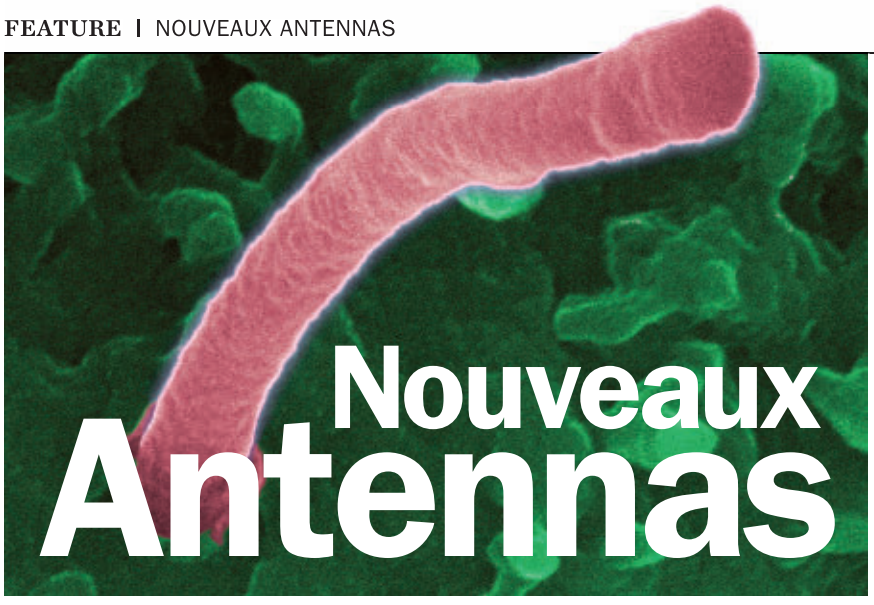
Superthin slices of semiconducting silicon and components made of magnesium perform the hardware and semiconducting tasks. The silk serves as scaffolding and packaging, which largely determines the lifetime of the device. So a unit might have a magnesium resistor, a silicon diode and a capacitor made out of magnesium and magnesium oxide. These delicate structures are stamped onto a sheet of silkworm silk and then packaged in more silk.

By liquefying the silk beforehand and then manipulating the concentration of various silk proteins, the researchers can package the device so it lasts for just a few days or for up to a year or longer, says study coauthor John Rogers of the University of Illinois at Urbana–Champaign. Calculations that incorporate chemical reaction rates, such as rates of solubility and diffusion, allow the researchers to predict and program the lifetime of a particular device.

In one demonstration, the scientists made a wireless-controlled implant that emits heat, killing bacteria. Three weeks after placing it in a rat's surgical wound, the device had nearly disappeared.

Testing is needed before such implants are used in people, but the ingredients have a good track record: Silk has long been used as sutures for wounds and safely disintegrates. The quantity of magnesium in the devices is far less than that in a daily vitamin. Silicon has also been investigated as a means of delivering drugs to specific sites in the body.

In the new study, the rat's implant was designed to break down after absorbing a certain amount of body fluid. But it's possible that pH, temperature or other environmental cues might kick off the disappearing act.



Nouveaux Antennas

A primary cilium protrudes from a cell's surface. Once thought of as vestigial, these antenna-like structures turn out to be big players in human health.

A single hairlike appendage may allow a cell to sense the outside world

By Tina Hesman Saey

Television viewers may be tossing out their old rabbit ears in favor of sleeker digital receivers, but scientists are raising the microscopic equivalents of antennas to new prominence.

Most cells in the body, from light-gathering eye cells to kidney cells to brain cells, sport a single, prominent hairlike structure sticking out like an index finger flashing the No. 1 sign. While cells can have other protrusions that serve as propellers or sweep away mucus and debris, the No. 1 "primary" cilia don't whip or wiggle or brush anything along. For a long time, in fact, scientists have thought about primary cilia the way people think about their appendixes, as vestigial organs that may once have had a purpose but are largely useless today.

Evidence now suggests that primary cilia aren't just stray whiskers evolution hasn't gotten around to shaving off. Instead, these structures might be among the most important that a cell possesses. Scientists are coming to see primary cilia as a major means by which a cell communicates with the rest of the body. A single cilium is a cell's eyes and nose, GPS receiver and even weather vane.

"If you lose your primary cilia, you're pretty much unable to interact with your environment," says Bradley Yoder, a cell and developmental biologist at the University of Alabama at Birmingham.

In the last decade, researchers have pegged a host of health issues on malfunctioning primary cilia. Snapped or otherwise inoperative appendages can lead to kidney failure, cancer, cleft palate, extra fingers or toes, water on the brain, hardened arteries, obesity, high blood pressure and heart disease.

More recently, teams have also started getting a handle on what exactly goes wrong to lead to primary cilia–related diseases, disorders and developmental defects, collectively known as ciliopathies. Primary cilia turn out to be the main receivers for messages sent by a well-studied, prolific protein that guides an embryo's development and keeps cell growth in check.

But cilia are not like TV aerials that get only a few channels; crucial messages don't have to begin with a chemical signal. Mechanical forces, such as blood, urine and bone pushing and pulling on cilia, can also get communication started.

As researchers learn more about how these cellular appendages function, the efforts could point to new therapies to bring disrupted receivers back online.

Getting attention

To say that primary cilia were completely ignored is not entirely fair. For a century, scientists have studied primary cilia in the eyes and nose. The rod and cone vision cells of the retina, in the back of the eye, stack light-gathering disks of proteins in their primary cilia. And primary cilia on specialized nerve cells in the nose, the only known exception to the one-per-cell rule, sense odors and react to them.

Such cilia, though, were viewed as anomalies. Similar singular protrusions from other cells were considered defunct leftovers with no purpose. Perhaps they were remnants of a murky past when cells swam solo, scientists thought (when they thought about primary cilia at all).

A first inkling that primary cilia other than those in the eyes and nose might have a purpose came from studies of people with polycystic kidney disease. This common genetic disorder strikes about one in a thousand people. It leads to large, fluid-filled cysts in the normally smooth kidneys that can result in organ failure and are a main reason for kidney dialysis.

Mutations in either of two genes cause a majority of polycystic kidney disease cases. When the genes were discovered in the 1990s, they were named for the disease: *PKD1* and *PKD2*. But no one knew what role their protein products played. In 2002, Yoder and colleagues found the proteins in the primary cilia on kidney cells — strongly suggesting that the cilia play a part in proper kidney function.

In hindsight, researchers probably should have suspected that cilia defects are behind cystic kidneys, says Maxence Nachury, a cell biologist and biochemist at Stanford. Clues gleaned from experiments with mice pointed toward the cilia as problem areas. A strain of mutant mice with cyst-distorted kidneys was found in 1994 to carry defects in a gene now known

THIS PAGE: J. REITER; OPPOSITE PAGE: NICOLLE RAGER FULLER

as *IFT88*. Thanks to work in green algae, researchers knew *IFT88*'s protein was involved with transporting molecules in the moving type of cilia, called flagella. The "*IFT*" stands for intraflagellar transport, the system that shuttles molecular cargoes in all cilia types.

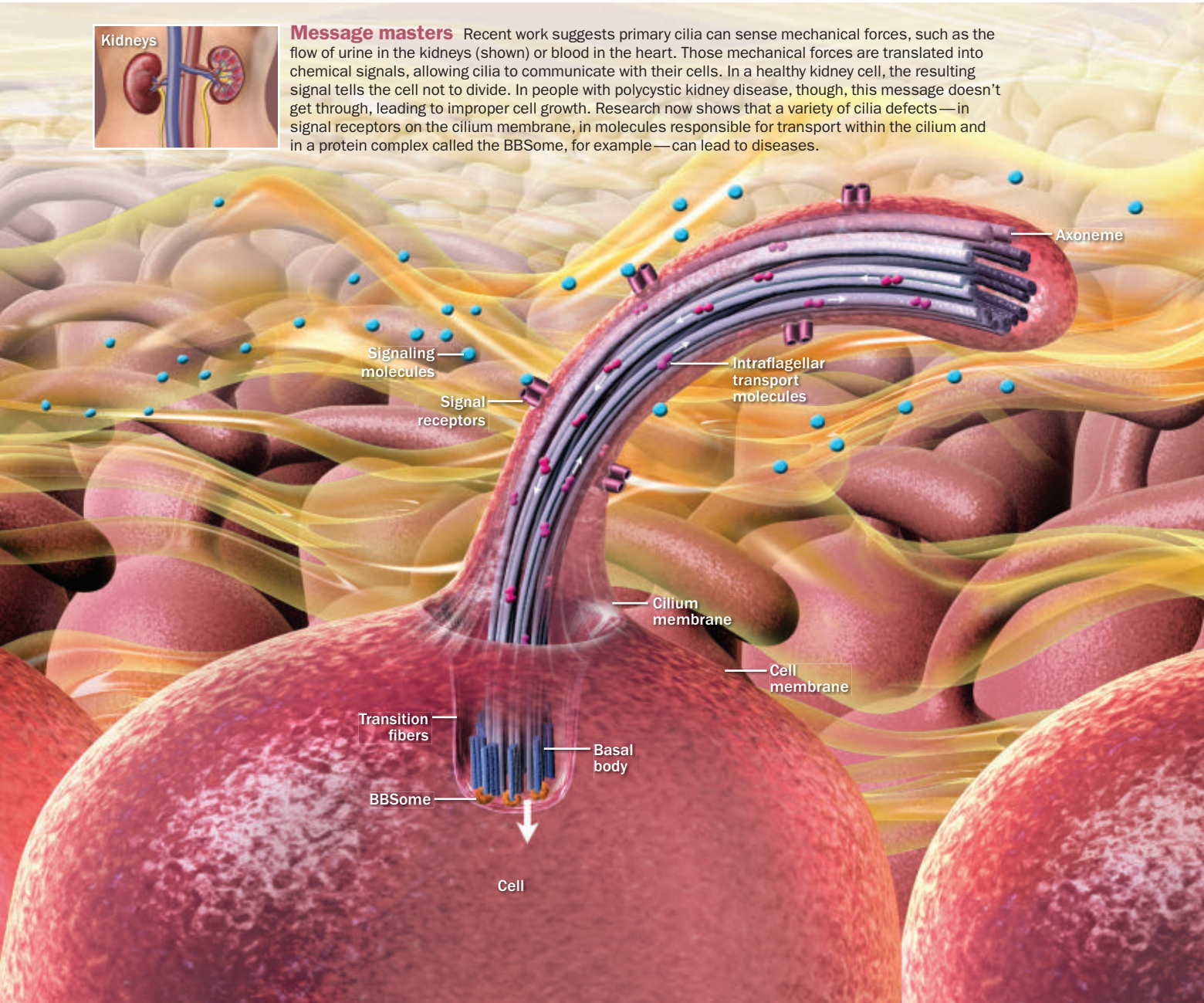
But people with polycystic kidney disease didn't appear to have mutations in the human version of *IFT88*, so it wasn't initially obvious that primary cilia would be to blame for the disease. Yoder's work strongly pointed to cilia as the culprits.

Armed with just the knowledge that cilia defects lead to kidney cysts, scientists still didn't fully appreciate what primary cilia could do, Nachury says. It took two more discoveries to cement cilia as a major force for human health and illness.

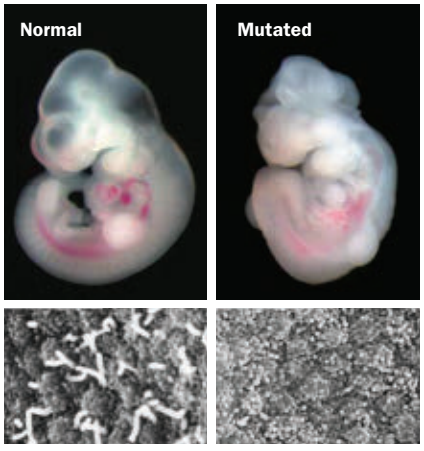
Cilia respected

Finding the cause of an obscure disease called Bardet-Biedl syndrome was the first big find. Patients with Bardet-Biedl syndrome, or BBS, experience a cluster of seemingly unrelated symptoms including obesity and vision loss, usually before the teen years. Many people with BBS have an extra pinky finger or toe. Some have heart defects. Cystic kidneys, learning disorders and loss of the sense of smell are some other common symptoms. Organs in a few people with the syndrome are even found on the wrong side of the body, though this may stem from a more general problem involving the moving kind of cilia (*SN: 9/26/09, p. 26*).

Today, these symptoms collectively scream "ciliopathy" to someone in the know. But not back in 2000 when the first BBS-linked genes were discovered. In 2003, proteins produced by these genes were found to crowd around the bases of primary cilia. Nachury and others have since discovered that seven BBS proteins and additional auxiliary proteins form a complex molecular machine known as the BBSome (pronounced bee-bee-sohm). That machine works like a



Message masters Recent work suggests primary cilia can sense mechanical forces, such as the flow of urine in the kidneys (shown) or blood in the heart. Those mechanical forces are translated into chemical signals, allowing cilia to communicate with their cells. In a healthy kidney cell, the resulting signal tells the cell not to divide. In people with polycystic kidney disease, though, this message doesn't get through, leading to improper cell growth. Research now shows that a variety of cilia defects—in signal receptors on the cilium membrane, in molecules responsible for transport within the cilium and in a protein complex called the BBSome, for example—can lead to diseases.



Mousy woes A genetic mutation that disrupts proteins responsible for moving molecules around in cilia can affect development, as shown by the mouse embryos at top. The mutated embryo lacks the kind of cilia (bottom left) that help it distinguish left from right.

bouncer sitting outside the passageway between the cilia and the rest of the cell, only taking down the velvet rope to allow select molecules into the club.

Discovering that disrupting the BBSome screws up cilia and leads to Bardet-Biedl syndrome gave primary cilia a bit of respect. But it still wasn't clear how problems with the little hairs could lead to such a wide variety of disorders. An answer to that question came from studying a prolific development protein, called hedgehog.

Hedgehog was first discovered in fruit flies. It sets an organism's body pattern from head to toe and right to left and carries out many other jobs in the body even after development is done, such as controlling when cells divide. Errors in hedgehog communication lead to birth defects, a type of skin cancer called basal cell carcinoma and perhaps heart disease. It's such a big-deal molecule that mammals have three versions, the most famous called sonic hedgehog.

Around the same time as the BBS result, Kathryn Anderson of Memorial Sloan-Kettering Cancer Center in New York City and colleagues were looking for genetic mutations that could scramble sonic hedgehog signals in mice. The researchers found that the genes controlling molecular traffic within flagella and primary cilia must be intact for sonic hedgehog to get its message across. Disrupting those genes interrupts sonic hedgehog's signal, so cells don't know where they are in the body or what they should be when they grow up, Anderson and others established.

Finding out that primary cilia are hedgehog receivers was the second respect-delivering discovery, because it revealed that these cilia are involved in development, are needed throughout life and play a role pretty much everywhere in the body, Nachury says. It also explained why they could be behind so many disparate types of diseases and defects.

Now that cilia are getting some respect, efforts have turned to studying how they work.

Sonic hedgehog, it turns out, floats up to a cell and docks with another protein called Patched1 in a cilium's outer membrane. This docking initiates a multistep biochemical reaction, sort of like knocking over the first in a long line of dominoes. As hedgehog bumps into Patched1, Patched1 releases Smoothened, which then topples the next domino and so on until the cascade activates genes that dictate what a cell will become or when it will divide.

Although cilia look as if they flow right into the rest of the cell, they are actually separate compartments with built-in barriers. Jeremy Reiter, a developmental biologist at the University of California, San Francisco, is trying to find out how to adjust the strength of these barriers. The efforts could lead to drugs for fighting some types of cancer, such as basal cell carcinoma.

In 2009, Reiter and his colleagues found that this cancer arises partly because Smoothened jumps the gun and starts knocking over other dominoes when it isn't supposed to. More recently, Reiter and colleagues have found 12 different compounds that bar Smoothened from the cilia, one of which may help scientists identify additional protein players. The team reported the results August 21 in the *Proceedings of the National Academy of Sciences*.

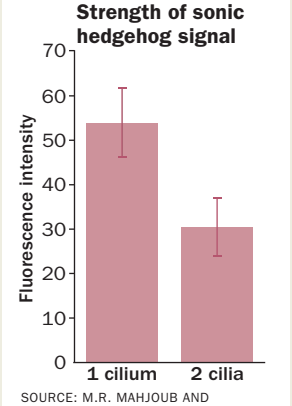
Jobs pile up

While researchers explore primary cilia's inner workings, others keep adding to the job list of these newly appreciated antennas.

For one, primary cilia on stomach cells help mice sense fat content in their diets and adjust stomach acid production, Juanita Merchant, a gastroenterologist at the University of Michigan, and colleagues reported in the August *FASEB Journal*. Mice fed a high-fat diet retracted primary cilia from stomach cells, the researchers found. Over time, this led to a drop in stomach acid

Pack 'em in

Although scientists now recognize the importance of primary cilia, it is still a mystery why cells create the compartments in the first place. Wouldn't it be better to place listening stations around the entire cell, to catch whispers coming from different quarters? One leading explanation is that cramming all of a cell's receiving equipment into one radio closet might make it easier for message-relaying proteins to find each other, thus strengthening the signal.



SOURCE: M.R. MAHJOUB AND T. STEARNS/*CURRENT BIOLOGY* 2012

Moe Mahjoub and Tim Stearns of Stanford University recently delivered some data to support the idea by creating cells bearing more than one primary cilium. Doubling or tripling the number of cilia on a cell meant that messages sent by an important development protein called sonic hedgehog were diluted by the time they reached their targets, the researchers reported in the Sept. 11 *Current Biology*. —*Tina Hesman Saey*

D. HUANGFU *ET AL*./*NATURE* 2003

levels. Less acidity could pave the way for stomach bacteria to move in and cause inflammation and possibly cancer, Merchant says.

But primary cilia sense more than chemical signals. They also pick up messages sent by mechanical forces, such as the flow of urine in the kidney. Kidney cells lining the tubes where urine flows dangle their cilia in the current. The force of the passing urine bends the cilia, triggering a different chain reaction from the one set off by hedgehog; this time one that starts with the proteins linked to polycystic kidney disease and ends with the cell electing not to multiply. Pulling dominoes from this chain means that kidney cells don't get the message to sit tight, causing inappropriate cell growth that can produce the cysts seen in the disease.

Not only do people with mutated *PKD* genes have kidney cysts, many also have heart defects or high blood pressure. Beerend Hierck, a cell and developmental biologist at Leiden University Medical Center in the Netherlands, now blames broken antennas for contributing to these problems too.

Hierck didn't set out to study primary cilia. He was, and still is, interested in heart development. While examining heart valve defects in chickens, Hierck noticed that some areas of the heart had bristly bits that made them rough, while others were smooth.

With painstaking electron microscopy work and other techniques, Hierck and his colleagues established that the bristles protruding from some heart cells are actually primary cilia. These cilia are involved in measuring how fast and in which direction blood is flowing.

This monitoring is particularly important during heart development. As the heart grows, blood flow gives clues to which cells should remain in the heart lining and which will migrate and form heart valves and other structures, the researchers reported last year in *Circulation Research*. The findings could help explain why children with absent or malfunctioning cilia sometimes are born with heart valve defects.

Problems in people A range of diseases have been linked to genes that direct the growth of primary cilia and control signaling within them. Common themes in these "ciliopathies" include developmental deformities and kidney cysts and failure.

Disease	Cause
Polycystic kidney disease is marked by the growth of multiple, painful kidney cysts.	Mutations in *PKD1*, *PKD2* or *PKHD1* genes disrupt primary cilia signaling that tells kidney cells to halt growth.
Bardet-Biedl syndrome leads to obesity, vision loss, deformed fingers and toes (above), and learning disabilities.	Mutations in 14 different genes can disrupt the BBSome, a complex of proteins needed for transporting other proteins into and around cilia.
Lowe syndrome includes early cataracts, mental retardation and kidney disease.	Mutations in the gene that codes for an enzyme called OCRL1 lead to shortened primary cilia.
Jeune asphyxiating thoracic dystrophy is a lethal form of dwarfism accompanied by skeletal, respiratory and kidney problems.	Mutations in the *IFT80* and *IFT88* genes, both part of the intraflagellar transport system, have recently been linked to the disease.
Alström syndrome includes seeing, hearing, skin, heart and kidney problems.	Mutations in the *ALMS1* gene, which produces part of the primary cilium's basal body, may be to blame.

Skeletal defects have been linked to faulty mechanical sensors as well. About three years ago when David Hoey, a biomedical engineer at the University of Limerick in Ireland, started studying how bone cells sense mechanical forces, he'd never heard of primary cilia. "I didn't really know what it was," he says. "I had to Google it."

Now, Hoey and others are building a case that primary cilia are stretch detectors that use the information they get to balance the constant building up and tearing down of bone.

Hoey studies osteocytes, octopus-like cells that hide in bones and reach their tentacles through crevices and tunnels to touch other types of cells responsible for the building and recycling of bone. Osteocytes need to measure mechanical forces to determine whether more bone is required or if the recyclers should be unleashed. Last year, Hoey and colleagues reported in *Biochemical and Biophysical Research Communications* that primary cilia on osteocytes sense fluid flow in bones.

It is unlikely that fluid flow bends the cilia of bone cells the way it does for cells in the kidney, he says. There's just no room in the dense matrix where osteocytes sit. Instead, the cilia probably detect stretching of the matrix occurring because of that fluid flow, sort of like a spider feeling its web wiggle. Figuring out how primary cilia tap into this spidey sense may point to possible treatments for conditions such as osteoporosis.

While most researchers are concentrating on understanding how primary cilia receive and interpret chemical, mechanical and other messages, Joel Rosenbaum, a cell biologist at Yale University, is thinking about the cilia in a new way. Rosenbaum's lab has long studied the flagella of the single-celled algae *Chlamydomonas*, and made major contributions to the understanding of the intraflagellar transport system. Now, he is exploring the notion that primary cilia might be transmitters as well as receivers.

A bit of evidence suggests he could be on to something. In 2009, a Japanese group showed that young *Chlamydomonas* release an enzyme called sporangin from their flagella during hatching. The enzyme triggers the tearing down of the mother cell's walls. Rosenbaum thinks the algae may send other signals via their flagella too.

If so, human cells may use their primary cilia as short wave communication systems, and transmission errors could be behind a whole new list of diseases. Rosenbaum is amassing preliminary data to support the idea, but he can't discuss the results until they are published.

Stay tuned. It's a good bet your primary cilia will be. ■

Explore more

- P. Satir *et al*. "The primary cilium at a glance." *Journal of Cell Science*. February 15, 2010.

A. KARAMAN/DERMATOLOGY ONLINE JOURNAL 2008

Suicidal THREADS

FASPHOTOGRAPHIC/SHUTTERSTOCK

Early abuse weaves its way into the brain, with potentially tragic consequences

By Laura Sanders

When sociologist Mike Tomlinson began combing through the health records of people in Northern Ireland, he wasn't interested in suicide. He was on the hunt for links between poverty and international conflict. But he came across a startling trend. From 1998 to 2008, the rate at which men in their mid-30s to mid-50s were committing suicide rose alarmingly fast, more quickly than the rate for the rest of Northern Ireland's population.

At first, that spike made no sense. A peace agreement reached in 1998 transformed Northern Ireland into a prosperous and tranquil place. Economic indicators had been surprisingly good. Suicide rates in neighboring countries were all gently falling. Nothing seemed to explain why so many of these men were killing themselves.

But Tomlinson found a hint in the men's pasts. They had all grown up in the late 1960s and the 1970s, during some of the worst violence Northern Ireland had ever experienced. Called the Troubles, this warlike period brought religious and political fighting that pitted neighbor against neighbor. Children of the Troubles lived with terrorism, house-to-house searches, curfews and bomb explosions. Trauma early in life had rendered men more vulnerable to taking their own lives later, Tomlinson proposed in July in *International Sociology*.

"If you were younger then, you carry that through," says Tomlinson, of Queen's University Belfast. This idea, that something that happened long ago could have such a profound effect today, seemed to resonate with others. When he described his idea to a suicide prevention group in Northern Ireland, "they

just lit on it, and said it speaks so much to what they were seeing."

Tomlinson does not study the brain, but his work has led him to an idea that's been under close scrutiny by people who do. Neuroscientists and psychologists now believe that childhood trauma, including violence and neglect, sears itself into the brain in ways that can have devastating effects later.

"It's a known fact that individuals with early life adversity are at a higher risk of suicide," says Gustavo Turecki, who directs the McGill Group for Suicide Studies in Montreal. A 2001 study in the *Journal of the American Medical Association* looking at more than 17,000 Californians found that harmful childhood experiences boost a person's lifetime risk of attempting suicide by two to five times. Other studies reveal that people who experienced adversity during childhood make up anywhere from 10 to 40 percent of people who later display suicidal behavior.

All the evidence suggests that childhood trauma can lead to suicide. Now, Turecki says, scientists have to figure out why.

In the last few years, they have begun to turn up molecular scars from past abuse. Some researchers have discovered chemical tags that change genes' behavior in ways that may contribute to suicide. And new evidence reveals that childhood trauma may throw off-kilter the hardware responsible for the brain's response to stress. For a person struggling with suicidal thoughts, dealing with stress appropriately can be a matter of life or death. As more and more signs of these brain changes turn up, the scientific community is struggling to understand how they affect a person's actions, thoughts and decisions — behaviors that sway a person's likelihood of committing suicide.

"This is something we see in the clinic," Turecki says. "People exposed to traumatic events seem to have a harder time adapting to life."

The immediate goal, researchers say, is to better identify people who are likely to act on suicidal thoughts. But in the future, a deeper understanding of the brain scars left by abuse might point to better treatments for someone battling against suicidal behavior, and perhaps even ways to prevent such tragedy.

Adverse experience category		Percent attempting suicide
Emotional abuse	No	2.5
	Yes	14.3
Physical abuse	No	2.2
	Yes	7.8
Sexual abuse	No	2.4
	Yes	9.1
Battered mother	No	3.1
	Yes	9.0
Substance abuse in home	No	2.6
	Yes	7.0
Mentally ill household member	No	2.6
	Yes	9.6
Parents separated/ divorced	No	3.0
	Yes	6.6

Upped risk A survey of California patients found strong relationships between adverse or traumatic childhood experiences and a person's lifetime risk of attempting suicide. Such links may suggest prevention measures.

SOURCE: S.R. DUBE *ET AL/JAMA* 2001

Something 'truly biological'

Worldwide, about 1 million people take their own lives each year. And the number appears to be growing: In the last 45 years, the suicide rate has jumped by 60 percent.

Every suicide is different. But when scrambling to explain why people would take their own lives, researchers look for similarities, any common strands that might make some sense of the senseless.

Men are more likely to die from suicide than women, though women are more likely to attempt suicide, the stats show. Caucasians are more likely to commit suicide than African Americans. Smokers, substance abusers and people with extremely low cholesterol are all more likely to die by suicide than their counterparts. Genetics undoubtedly plays a role, because suicides are known to run in families. The chemical messenger serotonin, best known for its job in regulating mood, also seems to have a part: People who commit suicide are thought to have dampened serotonin signaling.

But no one knows whether these factors are causes of suicidal behavior or just innocent bystanders that happen to show up commonly in people who commit suicide. That distinction isn't clear even for two of the strongest suicide predictors.

For one, most people who commit suicide are in the throes of an unmanaged psychiatric illness. And another, many of these people have recently experienced something very stressful, like public humiliation or a family problem, some precipitating factor that seems to send them over the edge. But attributing suicide solely to a stressor, or solely to a mental illness, is an oversimplified view, says psychiatrist J. John Mann of Columbia University and the New York State Psychiatric Institute in New York City. There must be much more to the story.

"What you see — and this is what the press gets locked into without looking beyond it — is an immediate precipitant. Job problems, scandal in the government, those kinds of things," Mann says. "But in

Marked early Researchers have identified a number of molecules that may play a role in suicide or related mental problems. Amounts of these molecules in the body can be modified by life experiences and environment, often via chemical tags that affix to DNA and influence how a gene behaves.

BDNF The BDNF protein, which helps brain cells grow and survive, is diminished in people who commit suicide. Chemical tags called methyl groups may influence the activity of the gene for BDNF, slowing protein production.

TrkB Low levels of this protein, which works with BDNF in the brain, have been linked to suicide. A DNA region that controls the gene for TrkB has more methyl tags in the brains of people who commit suicide.

Polyamines In people who commit suicide, gene activity controlling levels of polyamines — small molecules that help regulate cell growth and influence cell-to-cell communication in the brain — appears to be altered.

5-HTT This protein slurps up serotonin, which helps nerve cells communicate and has been linked to suicide. A DNA region controlling activity of the gene for 5-HTT had more methyl tags in abused children than in others.

fact, people are dealing with psychological stressors all the time, and compared to that, the number of people who die by suicide is tiny. Why doesn't that happen all the time if it's cause and effect?"

Something different, above and beyond a mental illness or an intensely stressful situation, is present in the brains of people who commit suicide, Mann contends. "Something truly biological is happening," he says.

Evidence now suggests that, in some cases, that something originates in traumatic early life experiences. The thread leading from a rough upbringing to suicide is quite strong.

Altered stress

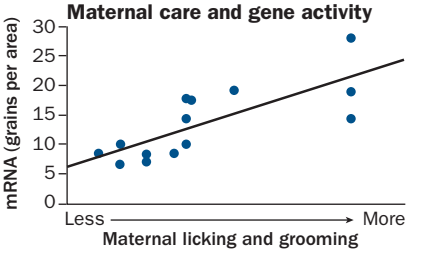
Rats aren't known to commit suicide, but a poor upbringing does have profound effects on their brains. Rats neglected by their mothers have brain changes that cause the animals to grow up with abnormal responses to stress, Michael Meaney of McGill University and his team found in a series of experiments in the 1990s. Turecki was intrigued by Meaney's results. "We thought the same mechanism might make sense in humans," Turecki says.

They turned out to be right. Turecki, Meaney and colleagues have now found changes in people similar to those seen in rats. And misbehaving genes in the brain seem to be behind both results.

By amassing a large collection of brain tissues from people who committed suicide, the researchers have been able to study genes, proteins and structures to look for similarities. One particular gene, found to behave abnormally in the neglected rats, caught the researchers' interest. This gene's activity level is low

Early comfort Rodents who got more affection from mom showed more activity in the gene for the glucocorticoid receptor, as measured by messenger RNA. This receptor helps shut down the body's stress response.

SOURCE: D. LIU *ET AL*/*SCIENCE* 1997



in people who suffered childhood adversity and later committed suicide, the team found. This wasn't true for people who had normal childhoods and committed suicide or for people who died in accidents.

The gene in question makes a protein, called the glucocorticoid receptor, that decides when the body's stress system has produced enough of the stress-signaling hormone cortisol and helps shut that system down. Without enough of this receptor, the body and brain can't reset after a stressful event.

In people who committed suicide who also suffered childhood abuse, a chemical stop sign was affixed onto the gene in a certain part of the brain, Turecki and his team reported in *Nature Neuroscience* in 2009. This stop sign, presumably attached during childhood, might stymie current and future production of the glucocorticoid receptor. (The team has no way of knowing the timing for sure because they can study the brain only once a person has died.) Since publishing that finding, the researchers have turned up further evidence: This stop signal, a chemical tag called a methyl group, is also present on several different parts of the gene that encodes the glucocorticoid receptor, Turecki and colleagues reported July 1 in *Biological Psychiatry*.

And the sensitivity of glucocorticoid receptor production to trauma seems to start early. Karl Radtke of the University of Konstanz in Germany and colleagues found similar methyl tags on the gene in blood samples of children born to women who experienced domestic violence while pregnant. Though the researchers can't say for sure what is happening in the children's brains or when the methyl tags first appeared, the results, reported online last year in *Translational Psychiatry*, do suggest that trauma in the earliest stages of development can have a lasting influence.

Genetic effects of trauma during childhood aren't restricted to the glucocorticoid receptor, either. In a study comparing brain tissue of 25 people who died by suicide and experienced childhood trauma with 16 people who died suddenly without abuse, control regions for more than 300 genes had differing methyl tags, Turecki and colleagues reported in the July *Archives of General Psychiatry*.

It's far from clear whether these genes have a role in suicide. Without large samples of people who experienced abuse without suicide, it's impossible to get at any clear links. But scientists are starting to figure out where to look next for possible clues.

A faulty axis

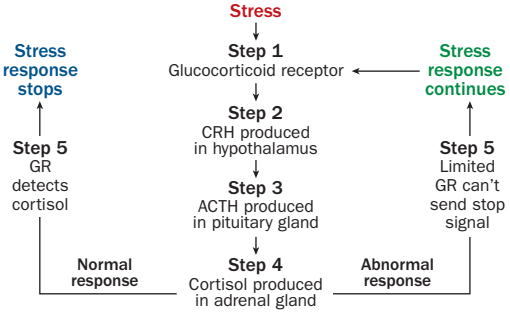
The glucocorticoid receptor is one small piece of the body's larger stress system, which may be molded in many ways by abuse in early childhood. Called the HPA axis, this stress-response unit is made up of three pillars: the hypothalamus and pituitary gland in the brain and the adrenal glands on the kidneys. In response to a stressful situation, the HPA axis kicks into gear, churning out stress hormones that help a person get through challenging times. During childhood, this system is shaped by the environment. As children grow up, the HPA axis hardens into its final form.

T. DUBÉ

Stuck on stress

The glucocorticoid receptor (GR) is key to the body's stress-response system. In a series of steps involving the HPA axis, stress hormones CRH and ACTH lead to cortisol production. Cortisol communicates with GR to turn off the response. In some people with early life trauma, there is not enough GR to get the "stop" message across.

SOURCE: E.C. COTTRELL AND J.R. SECKL/ *FRONTIERS IN BEHAVIORAL NEUROSCIENCE* 2009



Some researchers, including Turecki, believe that a stress-response system permanently altered by early life trauma could lead to suicide later.

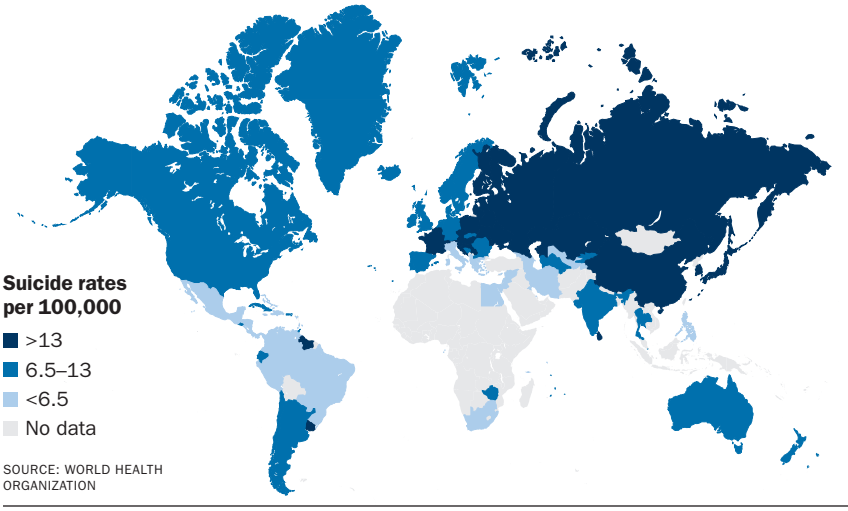
"To some degree, the message that you're getting is that the environment is hostile," Turecki says. "You're being abused by people you're supposed to trust, people who develop relationships of trust and attachment. When they're abusing you, the message you're getting is the world is one in which you can't trust anyone. You're always on alert."

Many studies, both in animals and in people, have found that adversity early in life programs this stress system for a quick ramp-up, like an engine that roars to life at the lightest tap on the accelerator. What's more, the engine keeps the RPMs redlined longer than it should.

Exactly how this system is sculpted by adversity in childhood is still unclear, but some animal experiments have yielded good leads. Changes in the structure and function of a brain region called the hippocampus, which is known to be sensitive to the kind of stress experienced during trauma and is also involved in controlling the stress response, seem to be involved. Levels of molecular players that fluctuate along with stress, such as the protein BDNF and the chemical messenger glutamate, could also be disrupted. And some results hint that early stressors can even staunch the production of new nerve cells, which may somehow preclude a normal stress response later.

Jussi Jokinen of the Karolinska Institute in Stockholm and colleague Peter Nordström have been turning up evidence for HPA axis malfunctioning in people at risk of suicide. Recently, the team has found that a stress response, measured by cortisol in the blood, lingers too long in young adults with mood disorders such as depression who have attempted suicide, compared with others with mood disorders who have not attempted suicide. Another study has found that the cortisol-producing adrenal glands weigh more in people who committed suicide, suggesting that the enlarged organs have adapted to pumping out massive amounts of stress hormones.

A global killer Almost 1 million people die from suicide every year, according to the most recent data from the World Health Organization. The map below shows suicide mortality rates but does not include suicide attempts, which can occur 20 times as often as actual deaths by suicide.



SOURCE: WORLD HEALTH ORGANIZATION

GEOATLAS/GRAPHI-OGRE, ADAPTED BY T. DUBÉ

From brain to behavior

As researchers move forward, the real challenge will be to identify the complex behaviors that may be the outward sign of suicide-associated brain changes.

Certain personality traits, such as anxiety, aggression, impulsivity and poor decision-making, show up in people exposed to childhood adversity. "We know there are alterations in executive function in kids who have been neglected," says child psychiatrist David Brent of the University of Pittsburgh School of Medicine.

And such traits also appear in people who commit or consider committing suicide. Brent and his colleagues have recently found poor decision-making in adolescents who have previously attempted suicide. In a classic lab gambling task in which people picked cards from different decks, these volunteers kept choosing to draw from the losing deck of cards long after other people identified the winning deck. The study, led by Jeff Bridge of the Nationwide Children's Hospital in Columbus, Ohio, was published in the April *Journal of the American Academy of Child and Adolescent Psychiatry*.

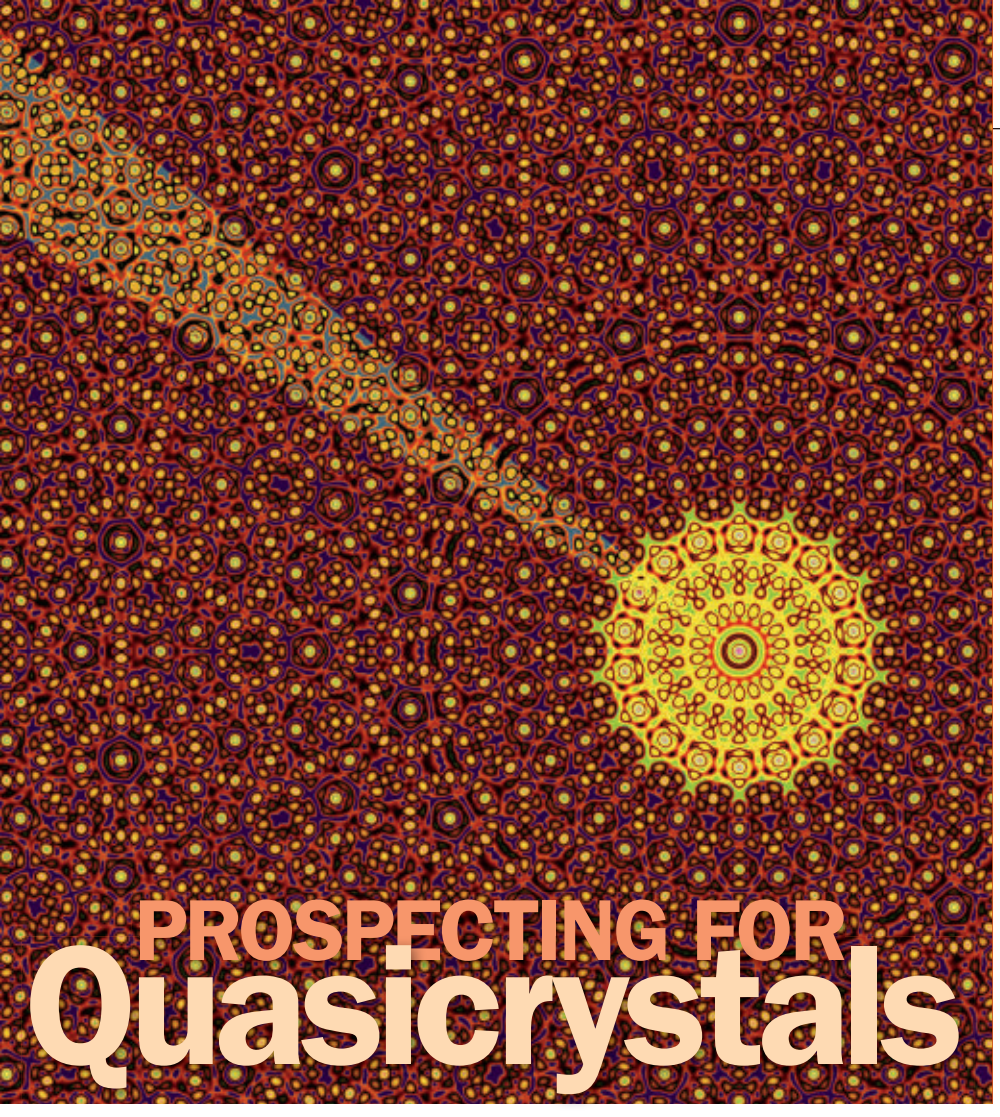
"What we have are different pieces of the puzzle," Turecki says. It's too early to draw clean lines from a hard childhood to a changed brain to behavior and on to suicide. And even if the relationship between early life and suicide were clear, the effect wouldn't apply to everyone. But the results, though incomplete, are starting to paint a compelling picture that could explain some — not all — suicides.

Although there are many loose ends, the work so far suggests that in some cases, early childhood adversity changes the brain in a way that primes it for self-destructive behavior. Bigger studies of more diverse groups of people will help reveal how all these diverse lines of data fit together, says Brent. "These strands converge," he says. "They converge on a person's ability to balance the will to live and the wish to die."

Often, when people come into a clinic or emergency room with signs of suicidal behavior, there's no good way to figure out whether those people are truly a risk to themselves or not. With a deeper understanding of how brain changes early in life can usher in a greater risk of suicide, doctors may be better able to better judge whose life is in danger. Particular behaviors and ways of thinking might be good outward signs of what's happening inside the brain, giving doctors clues about who needs the most help. "This is a story that's just beginning," Turecki says. "There's so much still to learn." ■

Explore more

- CDC Suicide Prevention: www.cdc.gov/violenceprevention/suicide



PROSPECTING FOR Quasicrystals

Siberian journey nets a mineralogical space oddity

By Nadia Drake

The rock came in a box labeled "khatyrkite." It didn't look like much, just a chunk less than a centimeter long with a whitish rind and studded with several dark metals. But when Paul Steinhardt got a good look inside, he saw something he'd been waiting years to see.

The quasicrystals nestled within displayed a bizarre symmetry that had never been seen outside the lab, an interlocking structure with no repeats. Steinhardt had been captivated by these almost-crystals since the early 1980s, when they were still a hypothetical form of matter.

But now, there they were.

Recovered from a museum in Florence in 2007, this rock holds quasicrystals that kicked off a Siberian adventure.

Where had they come from? And how could Steinhardt get more of them? Those questions launched a three-year quest culminating in an expedition to one of the most remote parts of Siberia — and a scientific discovery that has yet to be fully revealed.

Typical crystals are crafted from repeating units of atoms. These structures, in their 2-D form, are shapes that when fit together could fill a space completely — like squares or hexagons. In contrast, the units in a quasicrystal, short for "quasiperiodic crystal," are formed from units with symmetries that don't occur in normal crystals (*SN: 1/23/99, p. 60*). The shapes can't completely fill a space. If you were to tile your bathroom floor with, say, pentagonal pieces of just one size, you'd be left with gaps. You would have to use another shape as well. In the end, instead of a grid or honeycomb, your floor would look like the intricate mosaics decorating Islamic mosques and palaces.

Quasicrystals contain units that fit together in a nonrepeating way, as shown in this illustration. Repetition is lost as you move outward from the yellow concentric circles.

It was the early 1980s when Steinhardt, working at the University of Pennsylvania with graduate student Dov Levine, began investigating what would come to be called quasicrystals. At the same time, a few hundred kilometers away, Dan Shechtman was actually making quasicrystals, albeit unintentionally. Shechtman would publish a paper describing the first synthetic quasicrystals in 1984, and win a Nobel Prize for them in 2011.

Since Shechtman's discovery, more than a hundred quasicrystals have been synthesized in labs. Researchers suspected that the quasicrystals could be useful in electronics. But making them required idiosyncratic conditions such as an argon atmosphere, a vacuum and precisely controlled temperatures. No one knew whether the crystals could grow outside the lab, how strong they would be or how long they would remain intact. It seemed unlikely that quasicrystals could exist in nature.

Steinhardt wasn't satisfied with that. "I wanted to find something that was much older than anything made by humans," he says. "That would show that quasicrystals, like crystals, can be formed naturally and last a long time."

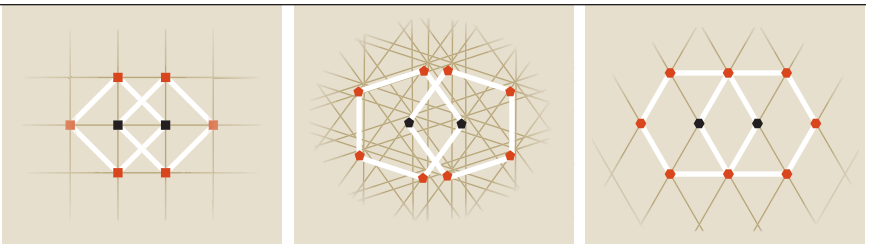
Searching through catalogs and pulverizing mineral samples turned up nothing. So in 2001, Steinhardt, now at Princeton, published a plea in *Physical Review Letters*. He asked curators and scientists to canvass their collections for candidate samples.

Years went by, and Steinhardt had no luck. Then, in 2007, an Italian geologist

FROM TOP: ERIC HELLER/SCIENCE SOURCE; P. STEINHARDT AND L. BINDI/*REP. PROG. PHYS.* 2012

named Luca Bindi came across Steinhardt's request while browsing an old issue of *PRL* — an unlikely reading selection for a geologist. Bindi, who works at the University of Florence, offered to search through the collection of more than 10,000 mineral specimens at the university's natural history museum.

There they found the khatyrkite. In 2009, Steinhardt, Bindi and colleagues announced in *Science* that the crumb of rock contained the first naturally produced quasicrystals ever uncovered.



Squares (left) and hexagons (right) fit together in an ordered, repeating way to create a lattice. Until the discovery of quasicrystals, pentagons (center) weren't believed to form ordered structures. They do in fact, but the pattern doesn't repeat.

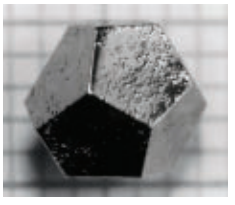
Finding Kryachko

What the *Science* paper couldn't say was where exactly the khatyrkite and the quasicrystals within had come from.

While the box pointed to Russia's Koryak Mountains, the researchers couldn't be sure. And they wanted to know if they could recover more chunks from the same area. They needed to find the person who found the rock.

That search turned into more than a year of dead-ends and misinformation — an investigation that Steinhardt and Bindi agree is way too complicated for a simple retelling. "It involves looking for missing persons, it involves finding some secret diaries, it involves looking for a strange Romanian smuggler, getting involved with someone who was either KGB or strongly KGB-connected, death threats to some of our people," Steinhardt recounts. "All kinds of blind alleys."

Finally the team managed to identify geologist Valery Kryachko, now in his 60s and working for a private company in Russia. Kryachko told them he had plucked the fragment from the Listvenitovyi Stream during an unsuccessful platinum prospecting trip in 1979. He didn't know until Steinhardt and Bindi tracked him down three decades later that the unusual chunk harbored something even more rare than platinum.



Quasicrystals have been made in the lab (example above), but scientists have long sought natural versions.

"What is tremendously fascinating for me is that Valery had in his hands the Florence sample, containing the first natural quasicrystal in 1979," Bindi says.

From there, the rock had gone on its own journey. Smuggled out of Russia in the 1980s, it eventually reached a collector in Amsterdam, who in 1990 sold his entire collection to the Florence museum. There it sat until becoming the inspiration for Bindi and Steinhardt's Siberian odyssey.

It came from space

While tracking down Kryachko, the pair was also trying to figure out how the mystery rock had formed. Was it of terrestrial origin, or a fragment of a meteorite? Could it be artificial, perhaps the by-product of some industrial process?

When Steinhardt described the rock to Lincoln Hollister, the Princeton petrologist noted that the quasicrystal component of the fragment contained metallic aluminum in an oxygen-free form that is impossible to find naturally on Earth.

"When you say impossible, do you mean really, physically impossible or do you just mean very, very unlikely?" Steinhardt recalls asking Hollister.

Very unlikely, it turns out. Oxygen-free aluminum could live thousands of kilometers beneath the Earth's crust, near the core-mantle boundary, Hollister said, but getting it to the surface would be problematic.

So Steinhardt looked skyward. At first, an extraterrestrial origin seemed improbable, but analyses conducted in 2010 did point to the stars.

In one part of the sample, the team found a bit of quasicrystal cocooned within a grain of stishovite. A naturally occurring, glassy compound, stishovite forms only under pressures 100,000 times greater than those on the Earth's surface — during an asteroid-on-asteroid collision, for example. That was the strongest evidence for an extraterrestrial origin for the quasicrystal, Bindi says.

The forms of oxygen in the sample, described earlier this year in the *Proceedings of the National Academy of Sciences*, clearly identified the rock fragment as a CV3 carbonaceous chondrite, coming from an asteroid born during the earliest days of the solar system, 4.5 billion years ago. But to prove that the quasicrystal, not just its rocky shell, was extraterrestrial, Steinhardt and Bindi needed Kryachko to take them to the rock's original resting place. "I decided that a trip to Chukotka was called for," Steinhardt says.

Panning for meteorites

In July 2011, Steinhardt and Bindi rendezvoused with their team in Anadyr, capital of Siberia's Chukotka region. Bordered in the north by the Chukchi and East Siberian seas, and by the Bering Sea in the east, the region is the part of Russia nearest to the United States. Getting into a longtime strategic defense zone meant using some creative language to convince the government, and military, to cooperate. "It's not the usual story of getting a Russian visa," Steinhardt says.

The plan was to head to the site in the Koryak mountains where the rock had first been found. Striking out overland meant embarking on a 350-kilometer journey atop spongy, shape-shifting

FROM TOP: © JOHAN JARNESTAD/THE ROYAL SWEDISH ACADEMY OF SCIENCES; AMES LAB, US DEPARTMENT OF ENERGY/WIKIMEDIA COMMONS

A long trek After arriving in Anadyr, Russia, Paul Steinhardt's team took a 350-kilometer journey (left) to a field site along the Listvenitovyi Stream (above), the locale where the first-known natural quasicrystal was unearthed. There, the researchers sifted through dirt looking for meteoritic rock that might harbor more examples.

tundra that's tricky to walk on, let alone drive over. Vehicles looking like minivan cabs parked atop tanklike treads carried the 13-person team deep into the mountains, through air thick with mosquitoes, streams packed with salmon and landscapes teeming with grizzly bears.

"I'm used to working in places that have things that try to eat you," says geologist and team member Chris Andronicos of Purdue University in West Lafayette, Ind. "I think that's also part of the reason I was recruited."

After four days, the team left the vehicles behind and backpacked another 1.5 kilometers. Here, Steinhardt would try to dig up his newest targets — siren-like shards that seem to have been calling to him since he first started studying quasicrystals.

Once near the stream, Kryachko took an afternoon to identify the spot where he'd recovered the original meteorite more than 30 years earlier. "Valery is an amazing person," Andronicos says. "I would've really loved to have been able to talk to him without a translator."

Andronicos, brought along to survey the region for the unlikely presence of a terrestrial quasicrystal factory, went to work scampering up local peaks. Rising a few hundred meters above the surrounding terrain, the Koryaks, though a popular destination for prospectors, are relatively unmapped. After exploring, Andronicos concluded that the quasicrystal was unlikely to have been produced locally.

Meanwhile, the others were mining the stream for meteorites. Though Listvenitovyi Stream is small, about 3 meters wide and 40 centimeters deep, the task turned out to be more complicated than expected. Clays at the stream's bottom were so heavy that they broke the team's shovels in less than 20 minutes, leaving the researchers digging up 1.5 tons of cold sludge mostly by hand.

But the sludge yielded a few potential meteoritic chunks — black and shiny, and only several millimeters across. "I observed a very promising grain the very first day," Bindi says. But on the way back home, no one believed there was any higher than about a 1 percent chance that they had found any pieces from the original meteorite, Steinhardt recalls.

"It was a major, major find when ... we found our first example of a grain that was clearly meteoritic," says Steinhardt. "It also had grains of a metallic phase that proved to be another example of quasicrystals. It was identical."

In all, Steinhardt says, he has nine more meteoritic samples, a find reported in September in *Reports on Progress in Physics*. Now, the researchers are studying these additional space crumbs, looking for and analyzing quasicrystals within. "This is a very exotic material, indeed," Bindi says. Though they won't disclose the newest results, team members promise the tale just gets weirder.

A Siberian trip turned up this meteoritic fragment, containing quasicrystals like those first found in the Florence museum specimen.

"I am certain this study will produce more than just a description of a mineral sample," says Robert Downs, a geologist at the University of Arizona who is familiar with the story. Downs notes that, because of their age and composition, there is a tantalizing possibility the meteorite's quasicrystals were born from a shock wave that swept through the dusty early solar system, the rippling product of a nearby supernova that eventually triggered the formation of the sun and planets. Ongoing analyses of these samples, he says, "will tell us something fundamental about the process that created the material that formed our solar system."

Though they're making the world wait a little bit longer to find out more, one thing is clear: Steinhardt and Bindi have shown that quasicrystals aren't just finicky, lab-grown oddities. The most extreme circumstances in nature can also create them, and they can endure for a long, long time.

"Our goal originally had been to find something fairly old, older than the last century, at least," Steinhardt says. "We overshot the mark. These are 4.5 billion years old." ■

Explore more

■ For more of Steinhardt's work: www.phy.princeton.edu/~steinh

The Spice Merchant's 1,750-Year-Old Silver Secret in the Sand

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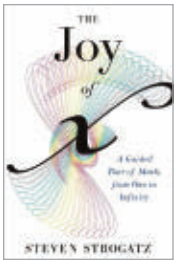
The Joy of X

Steven Strogatz

The world would be a better place, it is safe to say, if everybody had a basic understanding of mathematics and an appreciation for its scope and power. Economics, science and medicine, energy and the environment and diverse realms of public policy all depend on math as a guide to factual accuracy, sound judgment and intelligent opinion.

Sadly, the U.S. education system treats math like medicine to be crammed down students' throats because it is good for them, without much effort to explain why. Strogatz, a Cornell mathematician, has now provided a delightful antidote to the math phobia that infects most students exposed to the standard curriculum.

Based on a series of *New York Times* online op-ed columns, *The Joy of X* presents the essential ideas of the major branches of math in engaging and entertaining language. Strogatz cuts quickly to the core of everything from basic arithmetic — addition, subtraction, multiplication, division — to sophisticated realms such as group theory, vector calculus and quadratic equations. Each chapter explains how such math works and illustrates its relevance to everyone's life. (Math offers good advice on dating, for instance, and understanding vectors was the key to TV, cell phones and Wi-Fi.)



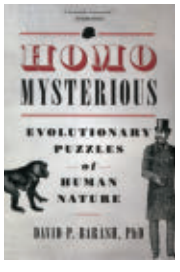
One slight quibble might be that the two chapters on statistics don't cope directly with how they are used to draw conclusions from scientific and medical research (a chapter exploring that issue would have been welcome). Nevertheless, anybody reading this book will come away with the deep understanding and appreciation for mathematics that 12 (or 16) years of formal education ought to, but rarely, provides. — *Tom Siegfried*

Houghton Mifflin Harcourt, 2012, 316 p., $27

Homo Mysterious

David P. Barash

Through an evolutionary lens, this book explores proposals — probable and improbable — that seek to explain the mysteries of human biology and behavior. Looking at questions such as what adaptive advantages, if any, human ancestors might have gotten out of developing the mental capacities for art, Barash provides no pat answers.



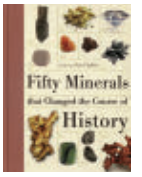
Instead, he delights in all that remains unknown and unexplained.

Among the most interesting questions is why women's ovulation is concealed not only to potential partners but also to women themselves. Barash describes one theory that posits hidden ovulation could give women more control over choosing a partner and when to mate. Other biological "puzzles" explored include breasts, female orgasm and homosexuality.

Barash, an evolutionary psychologist and biologist, then delves into how the human urges to create art and religion might have evolved. Fiction's appeal, for example, may have arisen from the human capacity for play. Both offer low-risk opportunities to learn about social rules. The emergence of human brainpower, he writes, might be linked at least in part to the development of cooking, or so one theory proposes.

Of course, not all that makes humans distinct is necessarily advantageous: Some traits may have simply persisted, accidental stowaways on evolution's journey. At its best, *Homo Mysterious* poses fascinating questions, and the potential answers are often informative. At its worst, the book speculates, never coming to a satisfying conclusion. But that, Barash argues, is exactly what makes these mysteries. — *Eva Emerson*

Oxford Univ., 2012, 329 p., $27.95



Fifty Minerals That Changed the Course of History

Eric Chaline

From alabaster to zinc, this book highlights the scientific, cultural and commercial significance of a bevy of alloys, metals, rocks and gemstones. *Firefly, 2012, 224 p., $29.95*

Owls of the World

Heimo Mikkola

Spectacular imagery enhances this detailed guide to 249 species of owls, including sections on owl biology, evolution and behavior. *Firefly, 2012, 512 p., $49.95*

The Science of Human Perfection

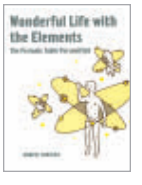
Nathaniel Comfort

A historian finds parallels between the 19th century eugenics movement and the rise of modern human genetics. *Yale Univ., 2012, 316 p., $35*

The Spine of the Continent

Mary Ellen Hannibal

A journalist travels the length of the Rockies documenting efforts to create a massive wildlife corridor stretching from Canada to Mexico. *Lyons Press, 2012, 272 p., $24.95*



Wonderful Life with the Elements

Bunpei Yorifuji

An artist explains the properties of the elements by drawing them as quirky characters in this fun guide to the periodic table. *No Starch Press, 2012, 206 p., $17.95*

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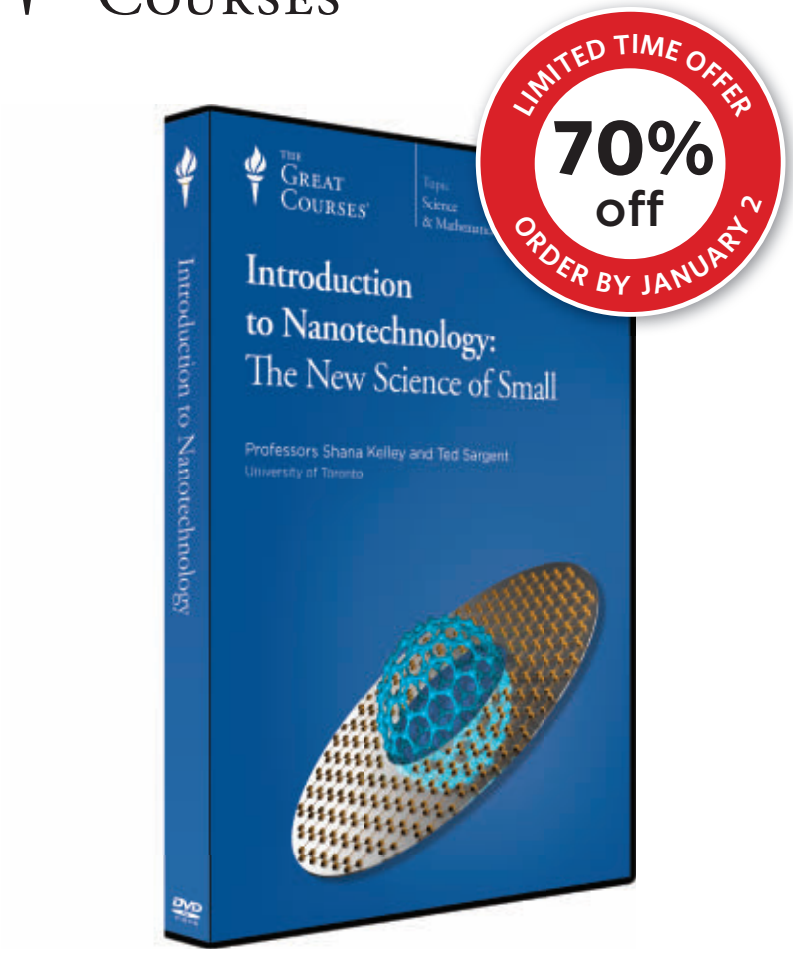

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Fractious debate

Rachel Ehrenberg's feature story on hydraulic fracturing ("The facts behind the frack," SN: 9/8/12, p. 20) spurred a big response from readers. We received letters voicing strong opinions on both sides of the fracking debate. The article was intended as an overview of what science has to say about the risks of fracking and, due to space constraints, could not cover every aspect of the issue. Here is a selection of the letters we received.

"The facts behind the frack" was right on the money — timely and well balanced. As a geophysicist, I've been asked by numerous acquaintances to explain the issue. As is often the case, the explanations are nuanced and qualified, as you say in the article, indicating the process is probably safe if properly regulated. Good job.
John Bodine, Naperville, Ill.

I found "The facts behind the frack" most informative. I was once a petroleum geologist, and I am pleased that this article shows a realistic and balanced picture of the benefits and possible problems of gas production via fluid fracking into shales.
Glen Stripling, via e-mail

Your illustration is dominated by "thousands of meters" of undisturbed horizontal beds of solid rock between the drilled layer and the water table. "Local geology" can indeed permit methane and fracking fluids to migrate upward, but so can typical geological folds, faults and cracks.
Ralph McGrew, Binghamton, N.Y.

The article "The facts behind the frack" was a useful summary, but left out one important part of the debate, the so-called Halliburton loophole. Why does the fracking industry insist on exemption from environmental regulations? Claiming "trade secrets" to hide essential components of their operations is little more than a smoke screen to prevent the public from discovering the hazards of which the industry is very well aware. Until the transparency Zoback admits has been missing is fully available, the public has every right to be suspicious and alarmed, and their "hysteria" is not at all "misplaced."
Michael Herzog, Naples, N.Y.

The article section "Is fracking fluid hazardous?" mentions that some 750 chemicals were in use by natural gas companies from 2005 to 2009. Not long ago, I learned that organophosphates make up part of a list of permissible compounds for fracking fluid. Organophosphates are substances closely related to nerve agents used in chemical warfare. Is there any truth to this?
Peter Klausmeyer, Lexington, Mass.

Many companies use their own formulations, some of which can be found at FracFocus.org, a registry of chemical information provided by industry. Organophosphates do act on the nervous system and are widely used as pesticides, but the website does not list any organophosphates as currently in use for fracking fluid. — Rachel Ehrenberg

Questions such as "Is fracking fluid hazardous?" are ludicrous. Fracking fluid is extremely hazardous, as the article goes on to prove. Do two other stories in the same issue ("Extreme heat rising worldwide" and "Groundwater use outpaces supply," *SN: 9/8/12, p. 10*) take place on a different planet? Fracking hastens climate change and uses billions of gallons of freshwater. It doesn't take a mathematician to add up the environmental and health problems and note that this sum far exceeds the benefits.
Kimberly H. Danforth, Clifton Park, N.Y.

There is no mention of the horrific toll this practice takes upon pristine lands. The carving of permanent roads and pads, the incredible environmental destruction, the belching of pollutants and climate-changing gases from thousands of truck journeys to each well, the exemption of these practices from EPA standards, the constant venting of fumes, the greenhouse gas emissions relative to other fuel sources or renewables — virtually none of these are discussed in this woefully incomplete story.
Lucas Lackner, Berkeley, Calif.

Where does the fracking water come from? Is water trucked in from a distant site? It seems the "environmental footprint" has to include the water source.
Pat Rapp, New York, N.Y.

Water use and disposal is an important part of fracking's footprint and differs depending on where the well is drilled. In semiarid or arid climates such as Texas, water use may be more of a concern than in wetter regions. There are similar concerns with how to dispose of the wastewater, which may be injected into wastewater wells, sent to wastewater treatment plants or used for deicing roads in winter, depending on the region. — Rachel Ehrenberg

The sedimentary rocks in which hydrocarbons are found are composed of thousands of individual horizontal layers with different compositions and mechanical properties. Such laminated systems are extremely resistant to the propagation of fractures (for example, abalone shells and plywood). Thus, as your article correctly states, incidents of groundwater contamination are likely due to other aspects of gas extraction such as improperly plugged wellbores or poor cement isolation rather than to fracking.
Bill Koerschner, Farmington, N.M.

One might expect higher water methane levels in areas with high levels of methane (one doesn't drill wells where there is no methane). Comparing water methane levels before and after fracking seems to be the only way to prove that fracking is causing the increased water methane levels.
Alan Bomberger, via e-mail

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To make sure microbes from Earth don't tag along on interplanetary trips, the Mars-bound Curiosity rover was assembled in a clean room.

Protecting the planet

Catharine "Cassie" Conley has the coolest job title at NASA: She's the agency's planetary protection officer. (The best title used to be "director of the universe," but a reconfiguration a few years back eliminated that job description, she says.)

Since 2006, Conley (right) has been charged with preventing Earth from being overrun by extraterrestrial microbes or other contaminants brought back by NASA explorers. She also makes sure spacecraft don't carry stowaways that could spread to other planets or later be mistaken for E.T. "I'm a policeman, basically," she says.

Only one other person in the world — her counterpart at the European Space Agency — has full-time responsibility for guarding planets, moons and other celestial bodies from contamination. "It's unfortunately a very small police force," Conley says.

But it's a job she was practically born to do. Conley's father was a mathematician who consulted with NASA to plot the trajectory of the Apollo missions to the moon. Her mother was a geneticist. "In kindergarten when they asked me what I wanted to be when I grew up, I said, 'genetic engineer,'" she remembers.

Eventually she became a cell biologist, but one with more broad-ranging credentials than usual. In college, Conley realized that space exploration is an international endeavor and added a major in language translation (Russian and French) to her science courses. Her combined background has helped prepare her to deal with international bureaucracy and to understand both the engineering challenges of missions and the biology of organisms she's trying to keep from colonizing other planets.

Before her current job, Conley worked at NASA's Ames Research Center in California. She and her colleagues sent tiny, transparent nematode worms into orbit aboard the space shuttle Columbia on its last mission in 2003. Surprisingly, the worms survived when the shuttle disintegrated and burned up on reentry, teaching Conley and NASA just how resilient life can be and reinforcing the need for planetary protection.

Keeping spacecraft from contaminating other planets not only ensures that Earth organisms aren't later mistaken for Martian life, it's also necessary to make sure that Earthlings — big or microscopic — don't become invasive or spread disease across the solar system, Conley says. She takes an object lesson from the European colonization of the New World, in which native populations were decimated by diseases carried by explorers. "That is exactly what we'd like to avoid," she says. — *Tina Hesman Saey*

Keeping Mars clean

A planetary protection officer's main job is to make sure that other planets don't become contaminated with Earth life. Spacecraft sent to areas where life-supporting ice or water could be found must meet the strictest standards. Here are a few examples of how NASA has protected Mars.

- **Viking landers** The 1976 mission's two craft were scrubbed and then baked. Even so, as many as 30 live organisms may have survived in the spacecraft, NASA estimates.
- **Spirit and Opportunity** Airbags used during landing were heat-treated to kill spores, and air filters and alcohol wipes helped make sure other parts didn't carry too many bacterial spores to Mars.
- **Phoenix** The spacecraft landed near Mars' north pole in May 2008. Most of the lander was scrubbed clean, and the arm used to dig into ice caps was also baked.
- **Curiosity** The new rover is the cleanest craft sent to Mars since Viking. It was scrubbed so that it had fewer microbes on its whole surface — an area roughly equal to a football field — than are typically found on a person's hand.

NASA

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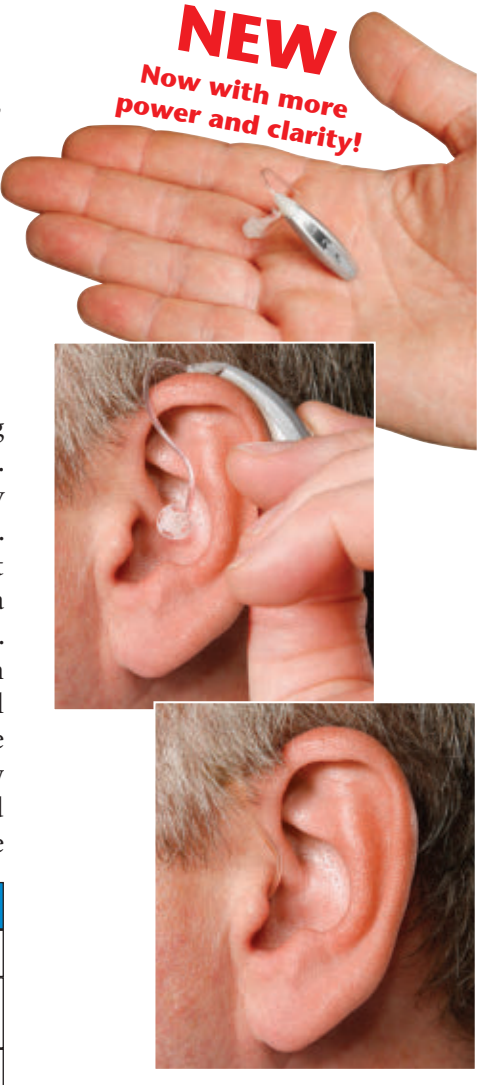

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