Inflationary Woes | The Descent of Music | Cancer Viruses

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ScienceNews

MAGAZINE OF THE SOCIETY FOR SCIENCE & THE PUBLIC ■ JULY 28, 2012

Higgs, Finally

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Peacocks Say It Infrasonically

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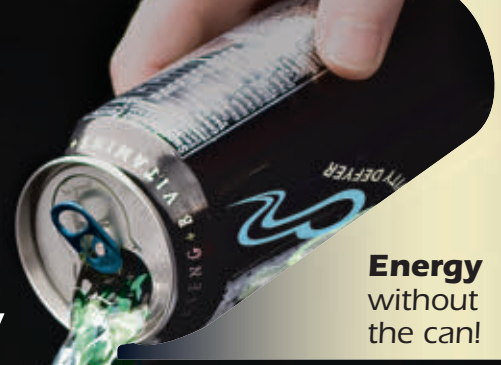

Energy without the can!

This is my story

I used to be more active. I used to run, play basketball, tennis; football… I

was more than a weekend warrior. I woke up every day filled with life! But now, in my late 30's, I spend most of my day in the office or sacked out in front of the TV. My energy has fizzled and I'm embarrassed to admit that I've grown a spare tire (I'm sure it's hurting my love life). Nowadays I rarely walk. For some reason it's just harder now. Gravity has done a job on me.

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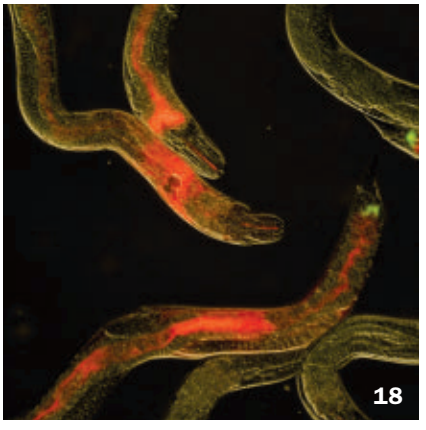

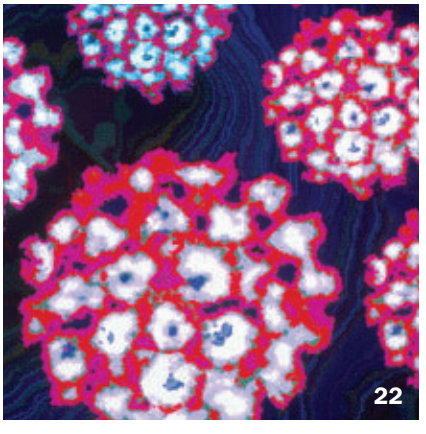

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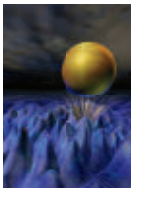

COVER The extreme energies reached in proton-proton collisions at the Large Hadron Collider pried the Higgs particle from its field. *Nicolle Rager Fuller*

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FROM THE EDITOR

Celebrating the value of telling the Higgs tale

When wire services transmit breaking news, they use labels like "bulletin" or "urgent" on the transmission to signal the magnitude of the story. On rare occasions, a really big story is designated by FLASH. Events warranting FLASH status included 9/11, the Kennedy assassination and walking on the moon.

On July 4, scientists reported the physics version of a FLASH-worthy event: the discovery of a particle presumed to be the Higgs boson, as Alexandra Witze reports (Page 5). It's the biggest physics news of the 21st century, allowing scientists to explain why some of nature's basic particles have mass.

For decades the most famous particle in the universe not actually known to exist, the Higgs completes the list of components of reality described by physics' "standard model." It's the particle form of stuff called the Higgs field, which sits everywhere in space and impedes the motion of other particles. Such resistance to motion is the defining property of mass, as I discuss in an essay in this issue (Page 28).

Subatomic particles like quarks and leptons have a mass that depends on how vigorously the Higgs field impedes them. Electrons, among the lightest particles, zip through it like a bullet through butter. For quarks, it's more like swimming through a vat of cold maple syrup. Photons, particles of light, breeze through the Higgs field with no slowdown at all, and hence are massless (and so can travel at the speed of light).

If the Higgs field didn't exist, all particles would be like photons. Without the varied menu of masses that particles possess, they wouldn't form the atoms and molecules that make stars, planets and people. So the Higgs field really is responsible for reality as humans experience it.

Only a little less grand than the importance of the Higgs, and the achievement of scientists in predicting its existence and then finding it, is the task of telling this story. Everyone who cares about where matter and life come from deserves to know how science finds those things out. Monitoring scientists in the quest for such knowledge, and chronicling their progress, their advances, false steps and triumphs, is a monumental challenge and responsibility. Science journalism, like all worthy professions, sometimes falls short of attaining its aspirations. But it's having the aspirations in the first place, and working always to narrow the gap between aspiration and actual achievement, that makes the enterprise worthwhile. — *Tom Siegfried, Editor in Chief*

JIM WEBB

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

Life on the road to Rome was full of danger for the grizzled and wily old spice merchant. The glorious Roman Empire he had been born into was suddenly collapsing into the chaos that would become known as the *"Imperial Crisis."* Triggered by a series of assassinations starting in 235 A.D., the Roman Empire was practically imploding under the combined pressures of invasion, plague, and civil war. As a wealthy trader who journeyed throughout the empire, the merchant knew that he possessed one thing the hordes of thieves and armed vigilantes would literally kill to get their hands on: his vast treasury of precious Roman silver coins.

Faced with this new world of lawlessness and fear, he simply could no longer travel with his riches so ripe for the taking. So one night, under a pale moon, he buried over 7,000 of his Roman Silver Denarii coins in a secret spot known only to him. No one knows what happened next, but this anonymous merchant's silver treasure would remain hidden in the ground for the next 1,750 years, until it was recently discovered, cataloged, and brought to auction.

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Say What?

Motor chunking ***\MOH-tohr CHUHNK-ing\ v.***

The process of learning a series of actions by grouping them into easy-to-remember "chunks." Dialing new phone numbers, for instance, often starts with the mental process of splitting 10 digits into three clusters — area code, first three digits, last four digits — and then dialing those until practice makes the motions automatic. Brain scans of people keying in sequences of musical notes show that motor chunking engages two different parts of the brain, a team of U.S. and U.K. researchers reports in the June 7 *Neuron*. The left hemisphere's frontoparietal cortex parses actions into chunks, while activity in both the left and right putamen, a brain region associated with body movements, links the chunks together. —*Allison Bohac*

Science Past | FROM THE ISSUE OF JULY 28, 1962

BATTLE AGAINST EXHAUST POLLUTION — The automobile exhaust problem is being attacked from many directions in an effort to preserve man's most necessary commodity, air.... In response to regulations by local and state governments and prodding from the Federal Government, several exhaust-trapping devices for cars have come on the market, none of which controls all of the poisonous gases emitted during combustion. One, the "blow-by" or crankcase ventilation system, has received Federal approval and will be standard equipment on all 1963 cars. There are at present two ways of monitoring automobile exhaust: 1. Recycling unburned exhaust gases back to the engine; 2. Reburning the gases in the exhaust system. Several manufacturers have marketed equipment utilizing these methods.

Science Future

August 5/6

NASA's new Mars rover Curiosity is scheduled to land on Mars late night August 5 Pacific Daylight Time (in the early hours of August 6 in the Eastern time zone). NASA TV will cover the landing live. Find updates on Curiosity at bit.ly/SFMarsland

August 16

The 21-and-up crowd can learn about the Big Bang in a Science Lounge event at the Denver Museum of Nature & Science. See bit.ly/SFdenverbang

SN Online

www.sciencenews.org

DELETED SCENES BLOG

The Higgs boson discovery leaked a day early when *SN* found a CERN video announcement. See "CMS spokesman: 'We've observed a new particle.'"

SCIENCE & THE PUBLIC BLOG

Huddling together during hibernation puts bats at risk for disease. See "Warning to bats: Cuddle not."

HUMANS

The earliest signs of people drinking cattle milk show up in 7,000-year-old pottery. See "Ancient North Africans got milk."

BODY & BRAIN

A study in Oregon finds growing gaps in childhood immunization schedules. Read "More adults put off kids' vaccinations."

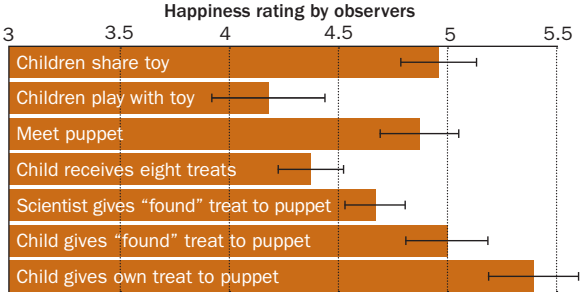
Introducing | MEET YOUR OTHER COUSIN

A genetic portrait of one of humankind's closest ape cousins has been unveiled for the first time. An international team of researchers reports the complete genetic blueprint of a female bonobo named Ulindi (shown) in the June 28 *Nature*. Humans have a tangled evolutionary relationship with bonobos and chimpanzees, the study shows. About 1.7 percent of human DNA is more similar to chimps than to bonobos, while another 1.6 percent is more closely related to bonobos than chimps. Untangling the genetic relationships may tell researchers more about how primate social structures and behaviors evolved. — *Tina Hesman Saey*

Science Stats | GENEROUS TYKES

Toddlers bucked the stereotype of being all about "gimme" in an experiment with puppets. Observers rated kids as showing greater signs of happiness when giving their treats to the puppets than when receiving the treats themselves. L.B. AKNIN *ET AL/PLOS ONE* 2012

Toddler happiness during experiments



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“It’s a great day for particle physics, and it’s really a profound discovery about how nature works.” —PIER ODDONE, PAGE 6

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Body & Brain The male ‘pill’ is a gel
Technology From cacophony to music
Science & Society Roman Empire mapped
Humans The earliest European painters
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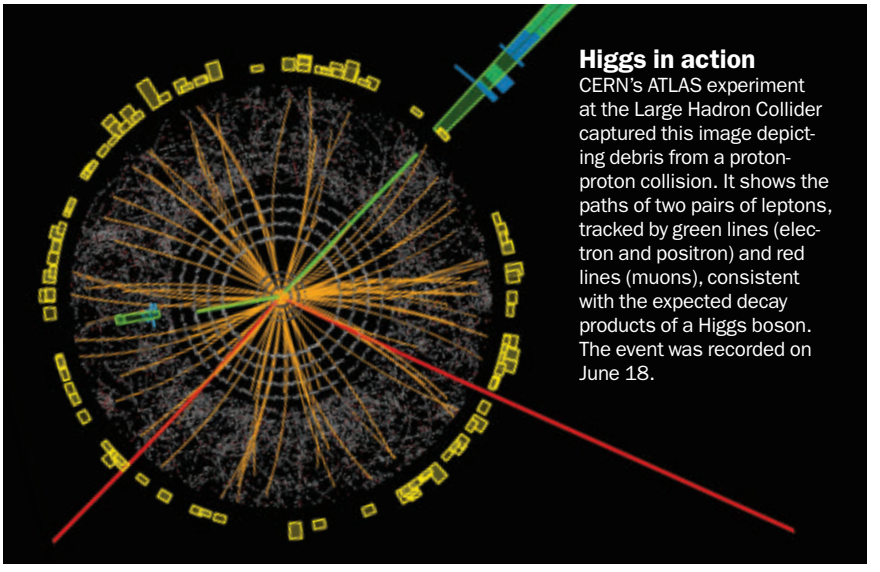
In the News

STORY ONE

Higgs boson fills last gap in list of basic particles

Little doubt left that physics’ standard model is complete

By Alexandra Witze



Higgs in action
CERN’s ATLAS experiment at the Large Hadron Collider captured this image depicting debris from a proton-proton collision. It shows the paths of two pairs of leptons, tracked by green lines (electron and positron) and red lines (muons), consistent with the expected decay products of a Higgs boson. The event was recorded on June 18.

Finally, physics’s zoo of subatomic particles is full. Scientists have almost certainly snared the Higgs boson, the last particle waiting to be roped into the fold.

Decades after it was proposed, the Higgs emerged in the shards of particle collisions at the world’s most powerful accelerator, the Large Hadron Collider at the CERN laboratory near Geneva. Physicists announced the discovery on July 4.

“We have now found the last missing cornerstone of the standard model,” said Rolf-Dieter Heuer, CERN’s director-general. “It’s the beginning of a long journey to investigate all the properties of this interesting particle.”

The particle’s mass is around 125 billion electron volts, about 133 times the mass of a proton. CERN captured the Higgs in two huge experiments, each of which independently reached the gold-standard statistical level for confirming the particle’s discovery.

Physicist Peter Higgs, who proposed the particle nearly five decades ago, joined in the all-around congratulations. “It really is an incredible thing that it’s happened in my lifetime,” he said.

In one respect, finding the Higgs simply confirms the standard model, physicists’ framework for understanding the particles that make up the universe and the forces that govern them (see Page 26). But the discovery also opens new areas to explore, including alternate versions of the standard model that could explain unanswered questions about the cosmos.

The Higgs traces back to 1964, when several physicists independently dreamed up the idea of an energy field that would have appeared in the early universe and permeated all of space (see Page 28). “In all honesty we were trying to solve a more modest problem,” said theorist Carl Hagen of the University of Rochester in New York. In certain theoretical calculations, particles with zero mass kept inconveniently popping up: In trying to get rid of those particles, Higgs, Hagen and others realized that once the universe cooled enough from its initial Big Bang, this energy field would have emerged.

Like a puddle of molasses, the field resists the motion of some particles moving through it. Such resistance to motion, or inertia, is the defining quality of mass. Subatomic particles acquire differing amounts of mass depending on how strongly they interact with the field.

Known as the Higgs field, its existence also required a new particle — the Higgs boson. (Bosons are a class of fundamental particles defined by their quantum properties.) The Fermi National Accelerator Laboratory in Batavia, Ill., had sought the Higgs until shutting down its biggest machine last year.

CERN scientists hunt the Higgs by smashing two beams of protons together at the $10 billion LHC. Out of a trillion proton-proton collisions, perhaps one will create a Higgs particle, which then decays almost instantaneously into other particles. Sensitive detectors monitor these smashups for signatures of several ways the Higgs might decay. “It’s not a needle in a haystack — it’s much worse than a needle in a haystack,” said Joe Lykken, a theoretical physicist at Fermilab.

Read more about the Higgs and its discovery at **www.sciencenews.org/higgsboson**

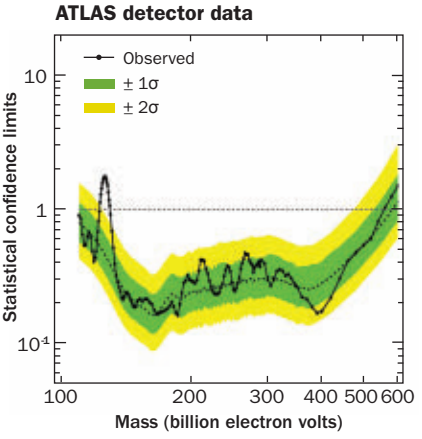
If each of the LHC's 500 trillion collisions were represented by a grain of sand, they would fill an Olympic-sized swimming pool, said Joe Incandela, a physicist at the University of California, Santa Barbara and a spokesman for one LHC experiment. Yet the grains from possible Higgses would cover only the tip of your finger.

Both LHC experiments looked at multiple ways the Higgs could decay, such as into two photons or into two Z particles.

CMS, one of the LHC's two main detectors, found signs of a particle with a mass of 125.3 billion electron volts, plus or minus 0.6 billion electron volts, Incandela said. The statistical strength of a signal is measured by a quantity called sigma: A 5-sigma result, the standard to claim a discovery, means there is a 1-in-3.5-million chance that a statistical fluke could have created a signal of that magnitude or greater.

In three of five decay paths studied, CMS found the Higgs with a statistical significance of 5.1 sigma. Adding in the other two channels, which have less data, lowered that to 4.9 sigma — but the results are still consistent with a Higgs being there, said physicist Elizabeth Simmons of Michigan State University.

The competing ATLAS experiment spotted a new particle with a mass of 126.5 billion electron volts, with a statistical uncertainty of 5.0 sigma when combining the decay paths it examined. Independent physicist Philip Gibbs combined data from ATLAS and CMS to come up with an unofficial estimate of a signal with significance of more than 7 sigma.



Higgs hunt Data from the ATLAS detector show no evidence of new particles at most masses (data below dashed horizontal line). But a blip at about 126 billion electron volts signals the likely presence of a new particle.

The Higgs masses found by both experiments are consistent with one another given the uncertainty ranges in each measurement, said ATLAS spokeswoman Fabiola Gianotti (though she did not give an error range for her experiment).

"It's a great day for particle physics, and it's really a profound discovery about how nature works," said Pier Oddone, director of Fermilab.

CERN won the transatlantic race to find the Higgs after Fermilab's proton-antiproton accelerator shut down last September. On July 2, in their final analysis, Fermilab physicists reported that they could narrow the Higgs mass range only to between 115 billion and 135 billion electron volts, with a statistical significance of 2.9 sigma (*SN Online: 7/2/12*).

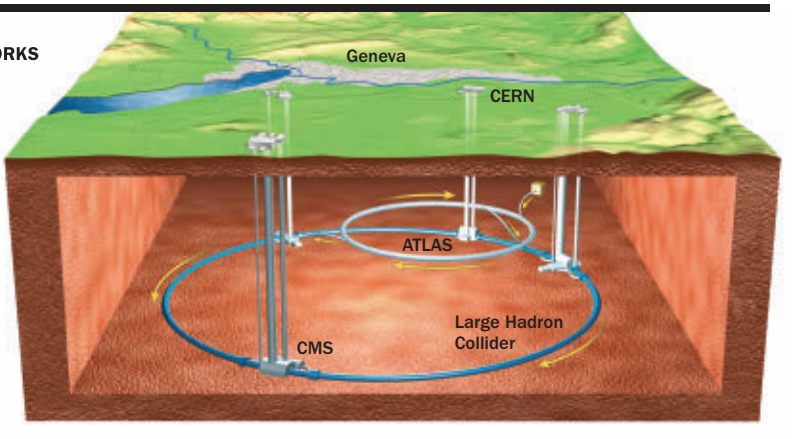
Since April the LHC has been colliding proton beams at energies of 8 trillion electron volts — 4 trillion in each beam. Lab officials have decided to extend the LHC's current run by up to three months to gather as much data as possible before it shuts down for two years for a major upgrade to 14 trillion electron volts.

So far, the particle seen in the experiments looks like the Higgs as predicted by the standard model, Heuer said, but slight differences could still exist. He compared the task ahead to trying to determine from afar if a person approaching is your best friend or your best friend's twin. Only when the person gets close enough can you determine which one it is. LHC data should soon reveal whether the particle's properties match standard model predictions or if new physics is at work.

One extension of the standard model is a theory known as supersymmetry, which holds that all known particles have a heavy "supersymmetric" partner as yet unseen. Several versions of supersymmetry predict that at least five kinds of Higgs boson should exist, although only the lightest would be detectable at the LHC. Other supersymmetric particles may account for dark matter, the mysterious stuff that makes up most of the matter in the universe but which scientists have yet to identify.

Back Story | HOW THE LARGE HADRON COLLIDER WORKS

Buried up to 175 meters deep beneath the French-Swiss countryside, CERN's premier particle accelerator hurls two beams of protons headlong into one another (arrows show paths). When they collide, the enormous energies generate other particles — including, presumably, the Higgs — that flash into existence, and then decay almost immediately. Giant detectors including the Compact Muon Solenoid (CMS) and A Toroidal LHC Apparatus (ATLAS) analyze the particle debris to determine what happened during the smashups. —*Alexandra Witze*



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Life

For longer versions of these and other Life stories, visit **www.sciencenews.org**

Peacock pomp makes a rumble

Male birds emit sounds too low to be heard by humans

By Susan Milius

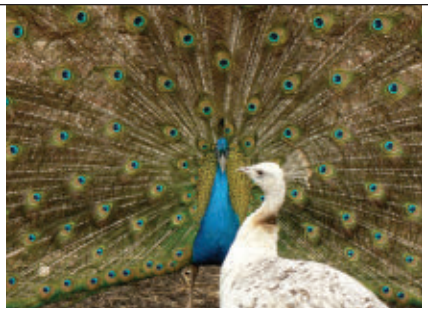
Unbeknownst to humans, peacocks may be having infrasonic conversations. New recordings reveal that males showing off their feathers make deep rumbling sounds that are too low-pitched for humans to hear.

Other peafowl hear it though, Angela Freeman reported June 13. When she played recordings of the newly discovered sound to peafowl, females looked alert and males were likely to shriek out a (human-audible) call. Peafowl are thus the first birds known to make and perceive noises below human hearing, Freeman said.

If peacocks can rumble, other birds may be able to as well, said Roslyn Dakin of Queen's University in Kingston, Ontario, who studies the visual allure of peacock courtship. "I don't think this is a weird case," she said.

Freeman, an animal behaviorist at the University of Manitoba, was inspired to make detailed recordings of peacocks by her coauthor's impression that their fanned-out feather display curved slightly forward like a shallow satellite dish. She found no evidence that the extended train gives any dishlike help in perceiving sounds, but her recordings did reveal throbs of sound below 20 hertz, the lower limit of human hearing.

Males were most likely to make the sounds during two common gestures. After spreading open the glory of his train feathers, a male shakes them, creating a ripple moving down the sides of the array or sending a shudder radiating outward from the base. During both these classic moves, all a person hears is a leaflike rustling, Freeman said. But infrasound thrums can carry for meters to birds out of sight in shrubbery.



As peacocks shake or shudder while opening their showy tail feathers, the birds make a low-pitched sound that is undetectable to humans.

The news that there's more to peacock communication than biologists had imagined doesn't particularly surprise Dakin. Familiar as the bird is, she said, "it's been talked about to a far greater proportion than it's been studied."

Chicks fare worse in noisier nests

Human-caused racket appears to cut baby bluebird survival

By Susan Milius

Baby bluebirds don't survive as well near traffic and other human-made noise as they do amid natural lullabies.

In a Virginia study, 35 percent more chicks died in the noisiest nests than in the most remote ones. Researchers found that chicks didn't adjust for the noise by begging for food louder or at different frequencies. So parents may not have gotten the right cues for nestling care, behavioral ecologist John Swaddle suggested June 12.

Baby eastern bluebirds (*Sialia sialis*) hatched in nests near human-made noise have lower survival rates than youngsters in more remote locales, a Virginia study finds.

Research on how human-made noise discombobulates birds has focused on how adults adjust their songs (or don't) or on what species will nest at all amid the din. Research is now turning to how noise might directly affect the success of a species.

Clutch size didn't shrink among eastern bluebirds (*Sialia sialis*), said Swaddle, a professor at the College of William and Mary in Williamsburg, Va. Birds settling into the 43 nest boxes he and his colleagues monitored for two years all started with about the same number of eggs.

Swaddle suspects that noise kept parents from caring for their nestlings properly. Microphones set up 15 meters from nest boxes revealed that human clamor could mask part of the nestlings' peeps. Adult birds often perch at about that distance from their nests when checking out the local situation.

Baby birds might have adjusted their cheeping to compensate for the noise. In nest boxes with real noises, though, the young bluebirds either couldn't or just didn't accommodate.

The 35 percent survival gap "is a really big number when factored into projections about a population's future," said Emilie Snell-Rood of the University of Minnesota Twin Cities campus. She pointed out that hopes for wildlife adapting to human menaces depend on having populations big and varied enough to make meaningful adjustments.

FROM TOP: JOEN12/ISTOCKPHOTO; STEVE BYLAND/SHUTTERSTOCK

"When you get extraordinary results, you need to look for extraordinary ideas to explain them." —NICHOLAS HUMPHREY

Case for cold-blooded dinos dims

Researchers show that mammals have similar bone growth

By Meghan Rosen

Life stories written in mammal bones are being used to debunk a key argument for cold-bloodedness in dinosaurs.

Annual growth lines etched in the leg bones of 115 wild warm-blooded mammals such as giraffes, reindeer and gazelles are similar to those previously seen in the remains of dinosaurs and other reptiles, researchers report online June 27 in *Nature*.

"People always said that mammals do not show these lines," says study lead author Meike Köhler, a paleontologist at the University of Barcelona. This assumption is "like a myth that's going around; you read it everywhere," she says. "But people haven't really studied mammals."

In reptiles, including dinosaurs, yearly cycles of growth are stamped in the bones like the rings of a tree. In fat months, animals pack on blood vessel–rich bone tissue. In lean months they lay down only thin sheets. Under a microscope, the slender sheets of bone look like dark lines. Because these "lines of arrested growth" or "rest lines" stripe bones, some scientists assumed that dinosaurs, like surviving reptiles, were cold-blooded. But the new work shows that warm-blooded mammals have banded bones, too.

Köhler's team analyzed bone slices from 41 species of ruminants — mammals with multichambered stomachs — native to 23 different climate zones, from the polar tundra of Norway to the humid subtropics of South Africa. Every mammal the researchers examined showed cyclical growth: fast and furious when food was plentiful, slow and sluggish when resources were scant. What's more, the rest lines from the specimens looked just like those seen in dinosaur fossils.

"It's probably not going to close the debate whether dinosaurs were warm-blooded or not," says paleontologist Martin Sander of the University of Bonn in Germany, "but the argument that [rest lines] mean cold-blooded is certainly not valid any longer." ■

Chimp recall feat may be mirage

Psychologist suggests ape sees numbers as colors

By Laura Sanders

In what seems like a blow for humankind, a very smart chimpanzee in Japan crushes any human challenger at a number memory game.

After the numbers 1 through 9 make a split-second appearance on a computer screen, the chimp, Ayumu, gets to work. His bulky index finger flies gracefully across the screen, tapping white squares where the numbers had flashed, in order. So far, no human has topped him.

Ayumu's talent has grown legendary since Tetsuro Matsuzawa of the Primate Research Institute at Kyoto University and colleagues first reported it in 2007.

But psychologist Nicholas Humphrey of Cambridge University in England says the hype may be overblown. In the July *Trends in Cognitive Sciences*, Humphrey floats an alternative explanation for Ayumu's performance: Ayumu might have synesthesia, a brain condition that makes him see numbers in colors. If Humphrey is right, Ayumu's feat isn't such a monumental accomplishment.

"When you get extraordinary results, you need to look for extraordinary ideas to explain them," says Humphrey.

Because synesthesia usually applies to strings of symbols like letters or numbers, there would be no reason to think that animals other than humans would experience it. No reason, that is, until Ayumu and his chimp colleagues learned numbers, Humphrey says.

If Ayumu does perceive the numbers on the screen in colors, then when the digits disappear each white square that replaces them would, in his mind, have a distinct aftereffect color. Ayumu could simply be ordering these colors in a learned sequence without having to remember the original numbers.

Humphrey's explanation is "speculative, in the best sense of the word," says neuroscientist V.S. Ramachandran of the University of California, San Diego. Work in Ramachandran's lab has found that synesthesia can give people an edge on visual tasks — the cross-wiring in the brain helps them remember better.

After seeing numbers 1 through 9 for only a fraction of a second (left), Ayumu touches them in order while they are obscured by white squares (right). His ability could stem from synesthesia, a recent proposal suggests.

T. MATSUZAWA/PRIMATE RESEARCH INSTITUTE

Body & Brain

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In lab tests, ozone exposures comparable to those experienced in Los Angeles (left) triggered inflammation and other heart changes in healthy volunteers.

Ozone raises cardiovascular risk

Pollutant triggers changes that can hike heart attack risk

By Janet Raloff

Breathing ozone at levels comparable to what might be encountered in the world's most polluted cities appears to cause potentially dangerous changes in the heart. Scientists have uncovered signs of inflammation and heart rhythm disturbances in 23 healthy young volunteers who briefly inhaled elevated levels of ozone, the primary irritant in urban smog.

The alterations, reported online June 25 in *Circulation*, go a long way toward explaining population data that have started linking ozone to an elevated risk of death from heart attacks and stroke.

Many air pollution scientists, "including me, have in the past thought [heart disease] associations with ozone were really associations with particles or some other pollutant," says Douglas Dockery of the Harvard School of Public Health. But he says the new study now directly shows that ozone is causing acute — and even chronic — risk for heart attacks.

For two hours on separate days, toxicologist Robert Devlin of the U.S. Environmental Protection Agency in Research Triangle Park, N.C., and his colleagues exposed men and women to clean air or to air containing 0.3 parts per million ozone. On the high-ozone day, volunteers inhaled the same cumulative dose that they would receive over eight hours in a place that reached the U.S. federal eight-hour limit of 0.075 parts per million.

Ozone reaches such levels in Los Angeles and Houston. And heavily polluted cities such as Beijing and Mexico City have experienced peak hourly ozone concentrations approaching the raw level used in the experiment.

A growing body of data indicates that inflammation underlies the progression of cardiovascular disease. In the new study, blood levels of several inflammatory agents increased after ozone exposure — sometimes more than doubling — throughout a period that lasted more than a day. This "caught us by surprise," Devlin says, and "we think it's one of the more important and significant findings."

Practice piano while you sleep

Not really, but hearing songs during rest may improve play

By Laura Sanders

Soft tones heard during sleep can creep into the napping brain and strengthen music-playing skills, researchers report online June 26 in *Nature Neuroscience*.

The results suggest that an existing skill can be sharpened during a nap, says study coauthor Ken Paller of Northwestern University in Evanston, Ill.

Earlier work has found that sound and odor cues during sleep can improve a person's memory for the locations of objects. The new study extends those results by showing that a learned skill — in this case, playing music — can also be influenced during sleep.

Before the easy job of having a nap, 16 right-handed participants learned two different not-very-catchy tunes, played with their left hands on the a, s, d and f keys of a computer. In an arrangement similar to that of *Guitar Hero*, circles that floated up the screen told participants which key to hit and when.

After this training, the volunteers' chairs were converted into comfy beds for a 90-minute nap. When scalp electrodes indicated that the snoozers had entered slow-wave sleep, a phase that's thought to be important for memory processing, researchers surreptitiously played one of the two songs the volunteers had just learned.

Once awakened, volunteers were better than before at playing both songs. But people improved more at the songs that they had heard during their naps.

This effect may be due in part to sleep spindles, waves of electrical activity that have been linked to memory processing during sleep. Spindles in the right premotor cortex — the brain area that controls movement of the left hand — were tied to post-nap performance.

Just because a skill can be sharpened during sleep doesn't necessarily mean that it should be, says sleep researcher Robert Stickgold of Harvard Medical School. "I think your brain does a lot of triaging at night. Now, you're trying to override that triaging and tell your brain what it should be worrying about."

STEINPHOTO/ISTOCKPHOTO

36 pounds Average five-year weight loss of men on testosterone

Testosterone is slimming for men

Five-year study finds weight loss in those taking hormone

By Nathan Seppa

Men with low testosterone who are given replacement doses of the hormone shed weight steadily for years, researchers in Europe reported June 23. Study participants, nearly all of whom were overweight or obese at the start of the study, lost 36 pounds on average.

"This was an unintended effect," said study coauthor Farid Saad, a research endocrinologist at Bayer Pharma in Berlin. "The big surprise was that when we analyzed the data [we found] that these men had lost weight continuously ... year by year." The men didn't diet as part of the study, and any increase in their activity was voluntary, Saad said.

He and his colleagues studied 116 men, average age 61, who had low testosterone levels. Each received quarterly injections of the hormone for five years. At the start, 71 percent of the men were obese and another 24 percent were overweight.

After five years, 97 percent of the men showed a reduction in waist circumference, on average losing "three to four trouser sizes," Saad said. Average weight dropped from about 236 pounds to 200.

"This definitely offers some insight that we can apply to our clinical practices," said Vineeth Mohan, a clinical endocrinologist at Cleveland Clinic Florida in Weston.

High testosterone levels have been linked to prostate cancer risk, and a small portion of men taking high doses of the hormone experience mania. But in this study, Saad said, men received testosterone in doses just high enough to bring them back to normal levels. Three men in the test group were diagnosed with prostate cancer during the study, a rate lower than the incidence found in routine screening programs for men that age, he said.

Fat tissue induces the release of cortisone and other chemicals shown to suppress production of testosterone, Saad said. The result is depressed mood, low energy and less activity. "This is a vicious circle that leads to more accumulation of fat mass and [continued] low levels of testosterone," he said.

Testosterone loss is not greatly governed by age. An Australian study also reported at the Endocrine Society meeting linked the hormone's decline more closely to obesity, diabetes and depression than to aging. Study coauthor Gary Wittert, a clinical endocrinologist at the University of Adelaide, reported that age had only a slight effect on testosterone levels in 1,382 men studied over five years, whereas depression had an effect two to three times as great.

That observation and other data suggest that "testosterone decline is not an inevitable result of aging among men," Wittert said. Rather, loss is attributable to "a variety of factors such as social demographics, health status, chronic disease, obesity and depression." ■

Male contraceptive shows promise

Hormone gel combination reversibly reduces sperm counts

By Nathan Seppa

Guys might someday have a birth control option that rivals the pill. Two gels applied to the skin deliver hormones that knock down a man's sperm count, acting as a male contraceptive, researchers reported June 25.

While women have had access to hormone-based contraceptives for decades, men have had few birth control alternatives beyond condoms and vasectomies. In the new trial, scientists randomly assigned 99 men in the Seattle and Los Angeles areas to apply two unlabeled gels to their skin daily. Some men got gels containing testosterone and Nestorone, a synthetic hormone related to progestin. Others got a testosterone gel and a placebo.

Men have had few birth control alternatives beyond condoms and vasectomies.

In all, 56 men completed at least 20 weeks of the regimen. By the end, 89 percent of men who got the dual hormone treatment saw their sperm counts plummet from about 15 million per cubic milliliter of ejaculate to less than 1 million. A majority of those men made no detectable sperm at all.

About 23 percent of men getting testosterone plus placebo saw their sperm counts drop below 1 million in response to that one-hormone treatment.

The approach "clearly deserves further investigation," said James Dalton, chief scientific officer at GTx Inc., a biotech firm in Memphis, Tenn. He noted that the research would need to improve on the treatment's 89 percent effectiveness rate.

The regimen inhibits activities in the brain's hypothalamus and in the pituitary gland that regulate sperm manufacture by the testes, said study coauthor Christina Wang, an endocrinologist at UCLA. But the treatment is reversible: The men's sperm counts returned to normal by about 12 weeks after stopping the medications.

The National Institute of Child Health and Human Development and the Population Council provided support for the study.

Large-scale testing of a single, combined gel will be needed to get regulatory approval for the drug combination.

Technology

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Evolution makes noise into music

Selection process makes annoying tones soothing

By Rachel Ehrenberg

Musicians, take note: An artistic mind isn't required to create appealing music. Starting with short sound sequences more grating than Muzak, scientists created pleasing tunes simply by letting the sounds evolve through a Pandora-like process of voting thumbs-up or thumbs-down on each sequence.

Inspired in part by long-running experiments probing the evolution of bacteria, computational biologist Bob MacCallum and colleagues decided to see if pleasant music could evolve from a cacophonous mess when human listeners acted as the force of natural selection.

The researchers started with a loop of simple audio waveforms and let it randomly change to generate a starter population with variation on which selection could act. Then more than 6,000 people listened to the audio loops and rated how much they liked the sounds on a five-point scale. Audio loops rated more favorably were allowed to mutate or combine with others to make a next-generation clip; the disliked ones died off.

By 500 generations, the pieces developed into pleasant little ditties with chord structure and rhythm, MacCallum and his colleagues report online June 18 in the *Proceedings of the National Academy of Sciences*.

Now the scientists are running experiments with stricter, more realistic sources of variation. The researchers also want to scale up the project, called DarwinTunes, to millions of users. "We may see a leap to a new plateau," says MacCallum, who spends most of his time investigating mosquito genomics at Imperial College London. "Done properly, we reckon the quality of the music would be pretty much comparable to current man-made electronic and dance music, but a lot more democratic." ■

Edison's battery gets a makeover

Redesigned nickel-iron cells might challenge lithium-ion

By Devin Powell

A rechargeable battery patented by Thomas Edison more than a century ago is staging a comeback. The nickel-iron battery may yet prove to be a viable power source for electric cars, as the legendary inventor had intended.

Thanks to a redesign, Edison's battery can now, gram for gram, store almost as much energy as the lithium-ion battery in Nissan's all-electric car, the Leaf. But the redesigned battery charges faster and promises to be cheaper and safer, researchers report online June 26 in *Nature Communications*.

"People abandoned this type of battery in the 1970s because there were better batteries at the time," says Hongjie Dai, a chemist at Stanford University. "We have made the Edison battery interesting again by drastically increasing the ability to charge and discharge it."

Edison's original design, patented in 1901, calls for two metal electrodes. A mixture of iron compounds and carbon gives off electricity that flows to a sheet of nickel, discharging the battery. Though hardy, it didn't usher in the revolution in electric cars that Edison had hoped for. Ultimately it was eclipsed by other technologies, including the lithium-ion battery, that stored and delivered more energy.

> "We have made the Edison battery interesting again."
> HONGJIE DAI

To resurrect Edison's battery, Dai and colleagues reshaped its electrodes at nanometer scales. Instead of simply mixing iron and carbon, the researchers grew iron pellets on top of atom-thick sheets of carbon chicken wire called graphene. Tiny plates of nickel perched atop carbon tubes formed the other electrode.

This attention to detail united each metal and its carbon counterpart via chemical bonds that provided a superhighway for electrons. A small prototype battery charged in about two minutes and discharged within 30 seconds, nearly 1,000 times faster than traditional nickel-iron designs. That speediness could be useful for juicing up a car in a hurry or storing and releasing the energy flowing through the larger power grid.

If scaled up for use in cars, nickel-iron batteries may be cheaper than batteries made from lithium, which is less abundant in Earth's crust. Also, the fluid electrolyte between iron and nickel electrodes isn't flammable, so the battery won't have the safety problems that have caused lithium-ion batteries to explode, says Dai.

Despite its advantages, the Edison reboot still has a way to go to prove itself. It faces competition from new lithium technologies under development that promise to store more than twice the energy in current lithium-ion batteries. And the researchers still need to show that their laboratory battery can scale up to larger sizes.

"Quoting power and energy density from small lab cells is not realistic," says M. Stanley Whittingham, a chemist at Binghamton University in New York. "Real cells typically have capacities of only 20 percent of the numbers calculated in the lab." ■

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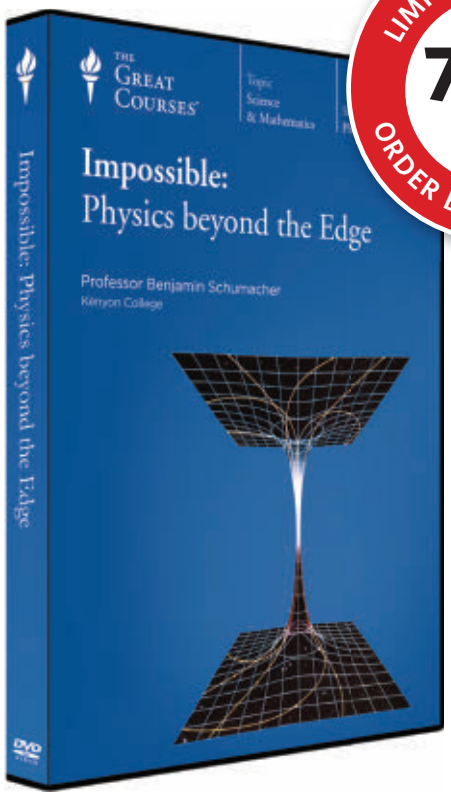

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Rome, by ship, carriage or foot

Map of ancient empire plots routes in days and denarii

By Rachel Ehrenberg

All roads may lead to Rome, but some are much smoother than others. A new interactive map of the Roman Empire that includes roads, rivers and hundreds of sea routes allows users to calculate the travel time and costs for traversing the ancient empire. Called ORBIS, the project is allowing researchers to probe the dynamics of an empire that had a profound influence on Western civilization.

The map, based on years of scholarship and new calculations, is organized around 751 sites in an area of about 10 million square kilometers. These sites were prominent settlements or important landmarks in an empire that once spanned one-ninth of the Earth's circumference and touched three continents. There are 814 road segments for a total length of 84,631 kilometers, and 28,272 kilometers of navigable rivers and canals. The map even incorporates data on wind and ocean currents, parameters that change drastically by season. Different modes of travel are also included, making it possible to calculate trip time whether traveling by civilian riverboat, military riverboat, wagon or rapid marching. And users can compare travel costs, based on price caps set by the Emperor Diocletian in 301 on more than 1,000 products and their delivery.

"It's not just an exploratory tool," said Elijah Meeks, a digital humanities specialist at Stanford who created the map with classics scholar Walter Scheidel. "It's also a representation of an argument."

Distinct military, political, economic and information networks emerge from the map, Meeks said. So the best way to transport slaves from Thrace to Capua might be entirely different than the optimal route for marching a legion of troops between the same two points. Like today, the preferred route can vastly differ if time is the priority rather than expense.

The importance of sea routes is striking. Compared with travel by mule (20 kilometers per day for heavily loaded animals) or fast carriage (67 km/day), sea emerges as the preferred mode of travel, allowing speeds of 80 km/day, Meeks reported June 19. The one notable exception is information. A 24-hour horse relay can move information 250 kilometers in a day.

Such a large-scale view of the empire brings much-needed context for scholars, said Maximilian Schich of ETH Zurich. "This map is really, really, really good."

Business wisdom from beet traders

Old Russian tax records hold hints for today's entrepreneurs

By Rachel Ehrenberg

Venture capitalists deciding whether to fund a new start-up could learn a thing or two from imperialist Russia. A new analysis of relationships among Russian entrepreneurs during the economic boom of the late 1800s and early 1900s reveals that the most successful teams were a mix of outgoing, gregarious networkers and cohesive, insular types.

Those ventures may have been trading in beets, barley and burlap, but they still hold lessons for doing business in the digital era. When investigating a new start-up, investors should consider the mix of founding members in addition to each individual's credentials, Brandy Aven, an expert in organizational behavior and theory at Carnegie Mellon University in Pittsburgh, reported June 20.

There's little consensus on what combination of partners makes for success, Aven noted. Members of tight-knit, cohesive teams cultivate trust and share knowledge and information well. But they may have fewer outside contacts and miss opportunities. Teams of brokers — people with wide and varied contacts — have access to new information and opportunities, but may lack trust and solidarity.

> "All things being equal, if I have two firms to choose between, I should go with the one with more diversity."
>
> BRANDY AVEN

To get at whether all-broker or non-broker teams fare better, Aven turned to data from late imperialist Russia, when railroads and population were expanding and there was explosive growth in private enterprise and industrial output. To best tax this burgeoning economy, the czarist state gathered data on all partnerships and joint-stock companies, including data on industry sector, team size and membership, firm location and how much capital it had raised.

Aven and Henning Hillmann of the University of Mannheim in Germany used these data to trace the relationships among team members for 2,053 Russian firms founded between 1869 and 1913. Teams that raised the most capital were functionally diverse — some members had a lot of outside connections, and some members were from tight-knit networks. "All things being equal, if I have two firms to choose between, I should go with the one with more diversity," said Aven.

Brokers may seem to have all the advantages: They are good at finding and using new stuff and at making money, said Ron Burt of the University of Chicago. "But once you are trying to get an operation running, closed can be better." ■

Humans

40,800 years — Age of oldest known cave art

20,000 years — Age of oldest known pottery

First Europeans may have painted

Study pushes age of earliest cave art beyond 40,000 years

By Bruce Bower

Red disks, hand stencils and club-shaped drawings lining the walls of several Stone Age caves in Spain were painted so long ago that Neandertals might have been their makers, say researchers armed with a high-powered method for dating ancient stone.

Hand stencils dot the walls of Spain's El Castillo cave. One dates to at least 37,300 years ago. A red disk painted in the same cave at least 40,800 years ago is the oldest known cave art.

Scientists have struggled for more than a century to determine the ages of Europe's striking Stone Age cave paintings. An improved technique that dates mineralized surface deposits finds that European cave art started earlier than researchers have assumed — at least 40,800 years ago, say archaeologist Alistair Pike of the University of Bristol in England and his colleagues. Previous estimates suggested that cave painting began no earlier than about 30,000 years ago.

Pike's team identified Europe's oldest known wall painting at El Castillo cave, where several chambers contain more than 100 illustrations. One of several large red disks dates to at least 40,800 years ago. A nearby hand stencil was made at least 37,300 years ago; dozens of other disks and hand stencils on the same wall probably come from the same period.

Artistic activity at El Castillo continued for nearly 20,000 years. A red disk in another chamber was painted between 36,000 and 34,100 years ago, and a black outline of an animal dates to at least 22,600 years ago.

Pike's team presents its findings in the June 15 *Science*. The researchers used a technique called uranium-series dating to analyze thin mineral deposits that had formed over or under parts of 50 paintings and engravings in 11 Spanish caves. Radioactive uranium incorporated into the minerals at the time of formation decays into a form of thorium at a known rate, allowing researchers to calculate the deposit's age.

Two dating studies at a German cave, one led by Daniel Richter of the University of Bayreuth in Germany and another by archaeologist Thomas Higham of the University of Oxford in England, place painted shapes, bone figurines and other artifacts often associated with modern humans at about 42,500 years ago. Those studies employed radiocarbon dating and a method to estimate the time since artifacts were exposed to a Stone Age fire, but not uranium-series dating.

"I think it is far more likely that all of the art at European sites was made by modern humans, although it's possible that a Neandertal hand was involved," Higham says.

Chinese pottery is oldest known

Ice Age ceramics predate agriculture by millennia

By Bruce Bower

Pieces of ceramic containers found in a Chinese cave date to between 19,000 and 20,000 years ago, making them the oldest known examples of pottery.

This discovery suggests that hunter-gatherers in East Asia used pottery for cooking at least 10,000 years before farming appeared in the region, say archaeologist Xiaohong Wu of Peking University in Beijing and her colleagues. Cooking would have increased energy obtained from starchy foods and meat, a big plus in frigid areas with limited food opportunities, the researchers report in the June 29 *Science*.

"The early onset of pottery making meant that food preparation intensified during the last glacial maximum," says Harvard University archaeologist and study coauthor Ofer Bar-Yosef.

The researchers gathered samples of bone and charcoal from soil layers at Xianrendong Cave in southeastern China that had previously yielded the pottery fragments. Radiocarbon measurements of those 45 samples point to human use of the cave from about 29,000 to 17,500 years ago. The pottery itself contains burn marks from being placed over fires and is 2,000 to 3,000 years older than pottery from another Chinese cave, which had previously held the age record.

Ceramics in a Chinese cave date to about 20,000 years ago, making them the oldest known examples of pottery.

Until about a decade ago, scientists assumed that heating clay to make ceramic containers began about 10,000 years ago with the rise of farming.

"Chinese pottery appeared long before animal domestication and has no obvious connection to the origins of agriculture or sedentary living," says archaeologist T. Douglas Price of the University of Wisconsin–Madison.

FROM TOP: COURTESY OF PEDRO SAURA; *SCIENCE*/AAAS

Environment

Lead stymies condor comeback

Birds unlikely to rebound fully without shift to nontoxic shot

By Susan Milius

The California condor's return to flying free in the wild after a close brush with extinction may be an illusory recovery.

The hundred-plus condors soaring over California swallow so much lead ammunition as they scavenge carcasses that the population can't sustain itself without steady medical care and continual resupply from captive populations, says toxicologist Myra Finkelstein of the University of California, Santa Cruz. She and colleagues describe analyses of lead in blood and feathers June 25 in the *Proceedings of the National Academy of Sciences*.

About 30 percent of blood samples collected annually from free-flying condors in California show lead concentrations high enough to affect the birds' physiology, Finkelstein and her colleagues report. Each year about 20 percent of the state's monitored birds flunk their lead test badly enough to need detox.

This grim paper confirms the toll of lead ammunition on condors in the wild, which conservation biologists have warned about for years, says Jeff Walters of Virginia Tech in Blacksburg. Regional or voluntary regulations do restrict ammunition in California and Arizona. But those rules don't seem to be solving the problem, Walters says.

The world population of free-flying California condors dropped to 22 birds by 1982, and biologists stepped in with an ambitious plan to save them. Even though no one had bred this condor species in captivity, biologists eventually trapped all the remaining wild birds to try breeding them. The effort succeeded well enough for biologists to start releasing condors back into the wild, albeit with plenty of monitoring and help. The same threats that eroded the species to begin with are still a menace, however.

Making the landscape safe for condors requires reductions in lead exposure, Finkelstein says. Even if only 0.5 percent of carcasses are tainted, a condor still has an 85 percent to 98 percent chance per decade of eating one that contains lead. Condors can live 60 to 70 years.

The California condor, a species that survived near-extinction, can't establish self-sustaining populations in the wild because of lead ammunition in scavenged carcasses, researchers say.

"I certainly would not want to see us let go of the condor—it's an iconic species of tremendous cultural value—but it's hard to justify a continued release effort until the lead issue is addressed," says conservation biologist David Wilcove of Princeton University. "It might well be better to call off the releases until regulators develop the backbone to do something about lead."

Walters predicts that a lead ban will eventually happen. "There is no doubt in my mind that use of lead ammunition is resulting in exposure of human children to harmful effects of lead," he says. "We just haven't documented the extent of this or its impact yet. Eventually this will go the way of lead toys."

Parents aid fry with low pH

A newfound ability of reef fish to adapt to shifting conditions over two generations indicates they might be less vulnerable to climate change than previous research suggested. In a new study, young anemonefish (*Amphiprion melanopus*) exposed to elevated carbon dioxide levels and warmer water grew more slowly and died at higher rates. But the fish showed no adverse impacts if their parents had lived under the same conditions prior to breeding. Researchers from James Cook University in Townsville, Australia, exposed adults for at least two months to conditions similar to the Great Barrier Reef today or to the higher temperature and lower pH projected to develop in the oceans over the next century. Then the adults were allowed to breed. A month after hatching, young anemonefish growing up under the experiment's most extreme temperature and pH exhibited comparable weight, length and survival to those raised in present-day conditions, researchers report in the July 1 *Nature Climate Change*. —*Janet Raloff*

FROM TOP: MOONEYDRIVER/ISTOCKPHOTO; E.J. WOODCOCK

"The assumption has always been that where you've got ice, nothing will grow in the water beneath it." —KEVIN ARRIGO

Microbes grow under Arctic ice

Thinner frozen layer fosters earlier blooms in odd place

By Devin Powell

Secret gardens may hide beneath floating slabs of ice in the Arctic. A pea soup of plantlike plankton has been detected extending out more than 100 kilometers under the ice off Alaska's coast.

The explosion of microscopic life, spotted last July, could cause problems for other critters in the Chukchi Sea, researchers report in the June 15 *Science*. Annual blooms typically happen later in summer, and only in open waters.

"I've been in this field for almost 30 years now, and I would have said this was impossible," says Kevin Arrigo, a biological oceanographer at Stanford University. "The assumption has always been that where you've got ice, nothing will grow in the water beneath it."

Light doesn't penetrate ice well, especially the thick ice historically found in the Arctic. Snow covering the ice can add an opaque blanket, making the water beneath a dim, dismal place for phytoplankton, which need light for photosynthesis.

But climate change has altered the character of much of the ice. Gone in many places are the meters-thick grand old slabs that once persisted year after year. New ice born every winter that tends to melt away during the summer is thinner and allows more light through.

Warmer air also melts snow and small grains of ice on top of young ice. This melt darkens the surface, like water poured on a sidewalk, allowing the ice to absorb more light.

More than half of the light striking a young slab of ice can reach the water below, the researchers found.

"The pictures of the ice on the surface are amazing," says Walker Smith, a biological oceanographer at the Virginia Institute of Marine Science in Gloucester Point. "There's no snow, and the ice is incredibly transparent."

After using a ship to crack open young ice more than a meter thick in places and peering beneath with underwater cameras, the researchers found phytoplankton growing at extraordinary rates. Fed by the light and by a steady stream of nutrients coming from the Bering Strait, the organisms thrived to depths of more than 50 meters.

What this prosperity means for the rest of the local food web isn't clear yet.

Sea rise speeds up on East Coast

Climate-related changes in ocean currents may be to blame

By Devin Powell

Property values aren't all that's been rising in Manhattan. The height of the water lapping up against the Big Apple and many East Coast cities has been creeping up faster in recent decades.

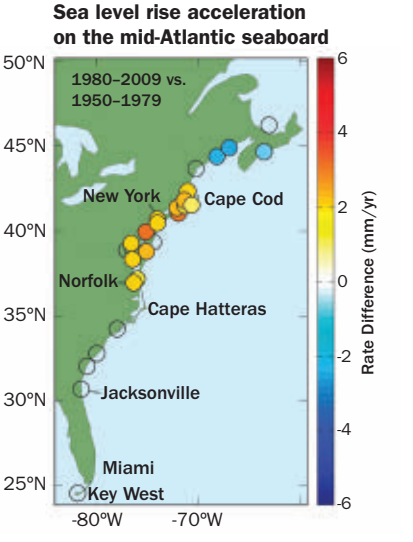
"We have direct evidence of a hot spot stretching from Cape Hatteras in North Carolina to just above Boston," says Asbury Sallenger Jr., an oceanographer at the U.S. Geological Survey's St. Petersburg Coastal and Marine Science Center in Florida. "The area has an unusual sea level rise acceleration compared to the rest of the United States."

Global warming could be driving the acceleration, researchers report online June 24 in *Nature Climate Change*. As temperatures climb, further sea level rise could increase the risk of flooding, encroach on wetlands and give hurricane storm surges extra punch.

Climate change has, on average, raised the surface of the world's oceans in recent decades by melting glaciers and causing seawater to expand as it warms. But the rise hasn't been uniform, like water filling a bathtub. It has happened at different speeds in different places thanks to wind patterns, currents and other regional factors that shape ocean surfaces.

Sallenger and his colleagues studied 60 years of data collected by sensors floating in the Atlantic Ocean. From 1980 to 2009, sea levels along about 1,000 kilometers of coast rose about 2 millimeters per year faster than they did from 1950 to 1979 — about three to four times the average global acceleration over that period.

Long-term climate trends may have created this sea level rise "hot spot" by changing ocean currents, Sallenger says. With the atmosphere heating, parts of the North Atlantic have warmed and gotten less salty. Computer simulations suggest the decreasing density of these waters could weaken the Gulf Stream and North Atlantic Current, which keep water away from the East Coast.



Rising waters Tide gauge measurements reveal spots along the East Coast where the increase in sea level rise was faster (yellow to red) from 1980 through 2009 than it was from 1950 through 1979.

A. SALLENGER *ET AL./NATURE CLIMATE CHANGE* 2012

Genes & Cells

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Tomato breeding sacrifices taste

Sugar-boosting gene turned off in quest for consistent color

By Susan Milius

It looks like 70 years of breeding for better color in unripe fruit has inadvertently helped create the wet-paper-towel flavor of the modern tomato.

Growers care about the green of unripe tomatoes, explains biochemist Ann L. Thomas Powell of the University of California, Davis. Ripening globes that are uniformly green let growers easily judge when a field will be ready for harvest. Over decades breeders have selected for this uniform green coloring instead of for tomatoes that turn a deeper shade around the stem end, Powell says.

The problem is, getting rid of that dark green zone, called green shoulders, turns out to have sabotaged a gene called *SlGLK2* that boosts sugar and other sources of flavor in the ripe tomato, Powell and her colleagues report in the June 29 *Science*.

"It is a good illustration of unintended consequences," says molecular biologist Harry Klee of the University of Florida in Gainesville.

A tomato's flavor appears to depend partly on whether it has a gene form that leads to a uniform light shade during ripening (bottom) or to a darker shade on top (left).

For years, Powell says, breeders assumed that a ripe red tomato got all of its sugars from the photosynthetic engines known as chloroplasts in the plant leaves. It turns out, however, that a green-shouldered tomato gets up to 20 percent of its sugars from its own chloroplasts. Without a functional *SlGLK2* gene, the ripening tomato forms fewer and punier chloroplasts that don't deliver, Powell and her colleagues have found.

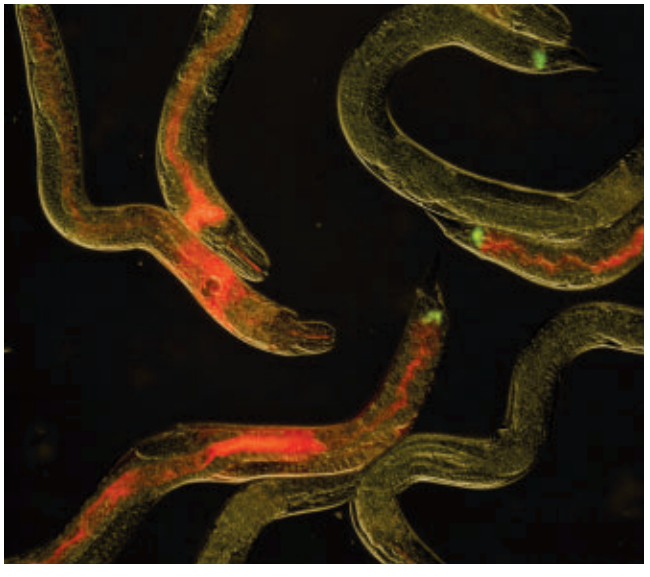
Skimping on sugars certainly could make a difference in flavor, says Klee, who routinely does taste tests in his lab. His tomato testing panels respond strongly to sugar content.

Volatile compounds wafting off a tomato's flesh also play a big role in its appeal. Inadequate chloroplasts don't produce as much of the chemical precursors for some of those compounds. "It's totally obvious you're going to take a hit in some of the volatiles," Klee says.

In the June 5 *Current Biology*, he and his colleagues highlighted the importance of a handful of volatiles — some of them mere whiffs — in seducing the nose and taste buds.

Exactly what the loss of the green-shoulders trait means for tomato flavor remains to be measured. But, Klee says, "it's not the whole story of why modern tomatoes are so bad, by a long shot."

Even under ideal conditions, genetic differences will matter in flavor. When Klee and his colleagues pamper various commercial varieties, taste panels pan some of them and give the best ones decent but not brilliant ratings. And just because a variety is an heirloom doesn't mean it tastes great, he cautions.



A bacteria's kill switch

Glow-in-the-dark bacteria living in nematode worms flip a genetic switch to change from peaceful cohabitants into killers. The M-form (M for mutualism) of *Photorhabdus luminescens* bacteria make friendly colonies (green) inside nematodes. But the microbes switch to the deadly toxin-producing P-form (P for pathogenic, red) when their hosts are ready to eat an insect from the inside out. Worms vomit up the bacteria into insects, and the bacterial toxins kill and help digest the feast. The transformation between mild-mannered and killer forms depends on the orientation of a piece of DNA called the madswitch promoter, Harvard and Michigan State researchers report in the July 6 *Science*. In the "on" direction, madswitch turns on genes needed for the bacteria to live inside worms and damps down production of substances that help kill insects. Bacteria with the promoter in the "off" direction are the killer type. —*Tina Hesman Saey*

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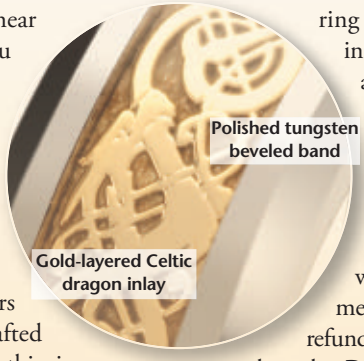

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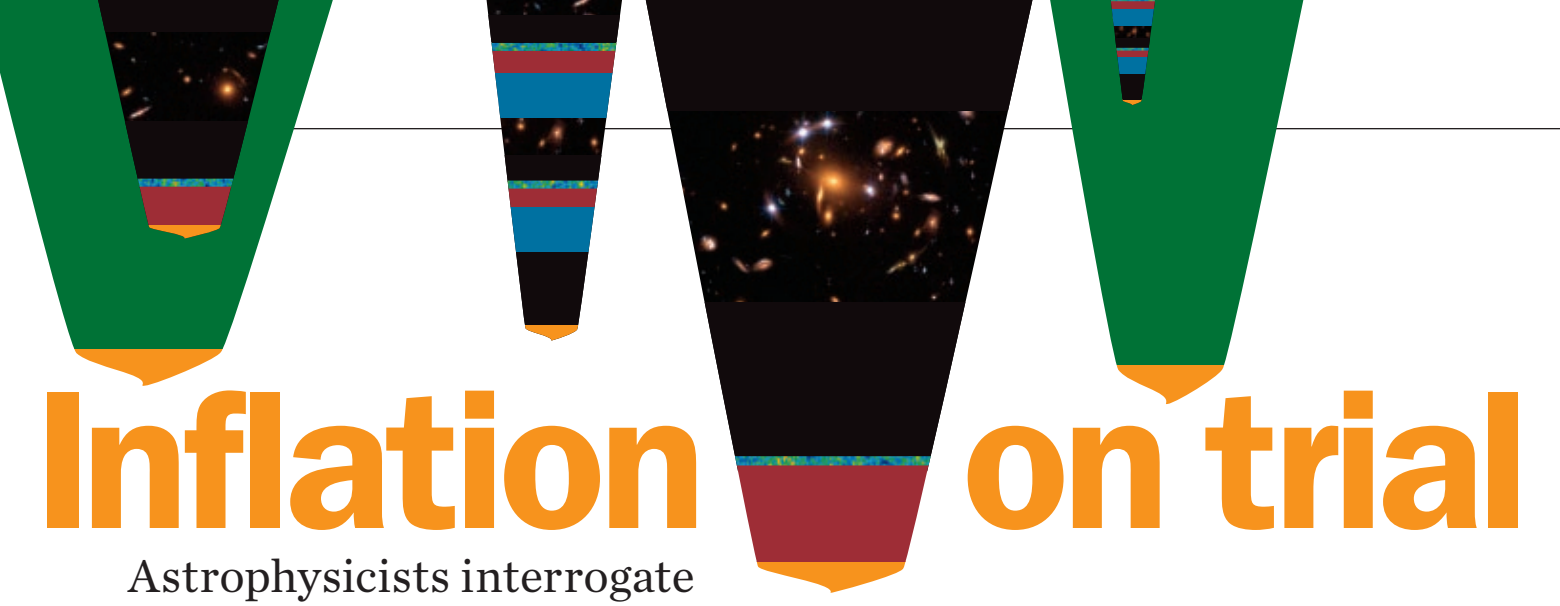


Inflation on trial

Astrophysicists interrogate one of their most successful theories

By Alexandra Witze

Ask any astronomer what inflation is, and you'll hear about the moment when the universe's primordial fireball expanded like a balloon on steroids, smoothing and flattening its initial wrinkles before it grew into the cosmos seen today.

Now, some physicists are trying to let a little air out of that scenario.

Generally regarded as one of the most successful theories about the early universe, inflationary cosmology is not exactly under attack. But a few scientists are questioning whether it deserves its reputation as completely untouchable. Inflation may be the best-developed explanation for many features seen in the modern universe, these researchers say, but it still has problems.

"The picture doesn't really hold together," says Paul Steinhardt, a theoretical physicist at Princeton University. "Either inflation needs a major overhaul or we have to think about some other approach to cosmology."

In a paper posted online at arXiv.org in April, physicist Robert Brandenberger of McGill University in Montreal argues that scientists should continue exploring alternatives to inflation rather than just taking for granted that it's right.

One such alternative, developed over the last decade, holds that the universe may not have begun with a single Big Bang, but rather experiences cycle after cycle of contraction and expansion. Another approach posits a world with a collection of tiny vibrating strings whose movements generate cosmic features currently explained by inflation.

Within the next few years, telescopes may collect enough data to distinguish among the options. Only then, say the inflation agnostics, will the picture hold together or fall apart.

"We really don't know what happened in the early universe," says Jean-Luc Lehners, a cosmologist at the Max Planck Institute for Gravitational Physics in Potsdam, Germany. "We know what the result was, but we don't know how the universe got there."

Those on both sides of the issue are quick to point out that inflation could turn out to be right. Inflation, says Andrei Linde of Stanford University, is "the only presently existing internally consistent theory of the early universe." Linde developed some of the first versions of inflation, and thinks those who question it are either intellectually off-course or led astray by journalists looking for a story. "It is quite possible that eventually this theory will be generalized and extended," he says. "But so far all attempts to replace it by something better failed."

The big balloon

In 1981 Alan Guth, now of MIT, proposed inflation and showed that it could explain two mysteries about the universe: why it is so smooth and why it is so flat.

Distant reaches of the cosmos look very much alike, even though they are too far apart to have had any contact after the universe was born in the Big Bang, 13.7 billion years ago. But if the infant universe had ballooned outward ridiculously quickly before slowing to a more leisurely expansion rate, this inflation would have smoothed out primordial disorder differentiating one region of space from another. Just a minuscule fraction of a second of inflation would have spread matter out uniformly except for tiny clumps — fluctuations in the background density — to serve as seeds around which the first protogalaxies could grow.

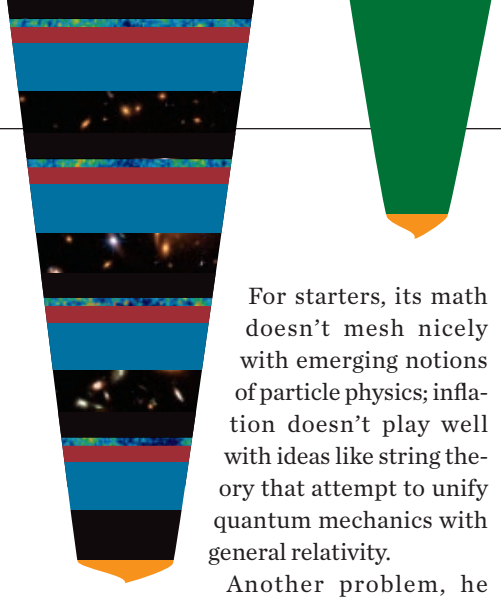
Such an "inflationary" period would also put the universe into the finely balanced state seen today, in which space on large scales seems very close to flat.

In 1992, the Cosmic Background Explorer satellite, or COBE, confirmed a key part of Guth's idea by measuring slight fluctuations in the leftover heat from the Big Bang. Later data from the Wilkinson Microwave Anisotropy Probe (WMAP for short) brought those cosmic fluctuations into even greater focus. Astronomers began talking about the arrival of an era of precision cosmology, in which detailed observations produced hard numbers that supported inflation.

But others aren't so sure. "We can't count the fact that our calculations agree with current observations as a success," says Brandenberger.

He has several problems with inflation.

SOURCE: J.-L. LEHNERS, ADAPTED BY B. RAKOUSKAS



A recent proposal blends an inflationary picture of the early universe with a cyclic scenario, creating a slew of universes with different histories. Some begin with inflation (yellow) and then undergo cycles of expansion and contraction (red and blue).

B. RAKOUSKAS

For starters, its math doesn't mesh nicely with emerging notions of particle physics; inflation doesn't play well with ideas like string theory that attempt to unify quantum mechanics with general relativity.

Another problem, he says, is that inflation requires density fluctuations in the infant universe to have wavelengths smaller than the Planck length, below which regular notions about space break down. "This is not to say that the calculations are wrong, but the calculations are extrapolations into regions where we cannot trust them," Brandenberger says.

Other recent work attempts to deal with new problems that inflation created. One phenomenon of concern is eternal inflation — inflation that never stops.

Guth's original concept called for inflation to end after a fraction of a second. But Steinhardt and others soon discovered that inflation would continue forever in a few rare spots, spawning rogue areas that went on ballooning. "That now turns the story inside out," Steinhardt says. "Instead of most of the universe being like us, most of the universe is inflating."

With eternal inflation, an infinite number of "pocket" universes can pop into existence. And in a universe where anything that can happen will happen an infinite number of times, it becomes impossible to determine what events are more or less likely.

Guth himself has wrestled with that last point, known as the "measure problem." In a paper posted at arXiv.org last year, he and Stanford's Vitaly Vanchurin describe efforts to define probabilities of events in an eternally inflating universe.

Not understanding eternal inflation doesn't mean inflation is wrong, though. "Many cosmologists, including me, believe that eternal inflation is the almost unavoidable consequence of our best understanding of the fundamental laws of physics," says Guth — meaning even alternative theories would have to cope with eternal inflation somehow.

Other pasts

Of alternative ideas, the one with the most traction comes from scientists including Steinhardt and Neil Turok, now of Canada's Perimeter Institute. It involves cycles of contraction and expansion (*SN: 9/22/01, p. 184*).

In this "cyclic scenario," the Big Bang isn't the beginning of space and time, but simply a transition from an earlier period in which the universe was contracting. It gets around the eternal inflation problem by smoothing out matter clumps during contraction. Any rogue areas are thus shrinking and don't become a problem.

Only after a period of contraction does the universe reverse itself and expand outward, so that astronomers today see distant galaxies rushing away at an accelerating rate. Yet this universe has its own problems, most notably that researchers can't properly describe the change from contraction to expansion.

Other alternatives to inflation include the "matter bounce" — which also relies on a switch from a contracting to an expanding universe, but using different mathematics. Brandenberger's favorite, "string gas cosmology," calls for a gas of tiny vibrating strings in the early universe, rather than a gas of particles, and thus meshes with string theory, he says.

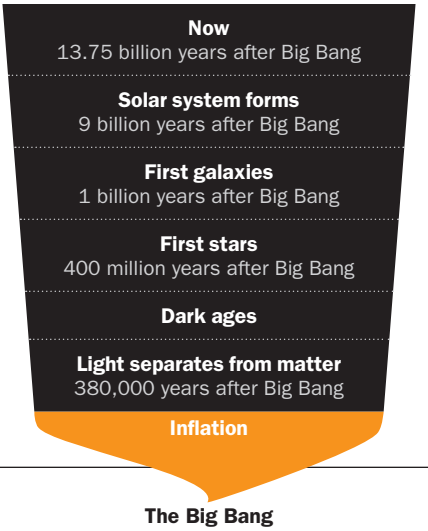
Still, most scientists say inflation remains a much stronger candidate than any of the other proposals. "All these alternative models are not justified either by observations or theoretically," says Viatcheslav Mukhanov of Ludwig Maximilians University Munich.

Ongoing experiments should reveal whether inflation will triumph in the end. Several efforts are now looking for a sign of inflation called gravitational waves. These disturbances ripple through spacetime from violent cosmic events like colliding black holes — or the Big Bang. Other clues may come from the European Space Agency's Planck satellite, launched in 2009 to build on the success of COBE and WMAP (*SN: 4/11/09, p. 16*). Planck is hunting for another subtle imprint on the cosmic microwave background, with initial results expected next spring.

One final approach may be to bundle the alternatives to inflation together. Lehners, for instance, has been working to combine eternal inflation with the cyclic universe. Each pocket universe created by eternal inflation, he says, could replay the cyclic scenario over and over again, in a sort of best of both worlds.

In the end, physicists will undoubtedly keep exploring both inflation and its alternatives, and the final solution may lie somewhere in between. "It's really harmful," says Lehners, "to assume that we know what the answer is going to be." ■

Quick growth In the most well-accepted picture of the early universe, a period of rapid expansion called inflation follows the Big Bang. Inflation explains many cosmic features visible to astronomers today.



Explore more

- R. Brandenberger. "Do we have a theory of early universe cosmology?" Online at arXiv.org/abs/1204.6108

The human papillomavirus (pink and white in this colored micrograph) is a known cause of cervical and other cancers.

DR. LINDA M. STANNARD/UNIV. OF CAPE TOWN/PHOTO RESEARCHERS, INC.

Catching a cancer

Viral culprits may explain a host of tumors with as-yet unknown triggers

By Laura Beil

Mentors at the Rockefeller Institute had warned Peyton Rous not to waste his career fooling with "the cancer question." Then he got the bright idea that tumors might be contagious. Rous extracted part of a sarcoma from a hen, strained out the cells and injected the remnants into another bird. The second hen also developed cancer. Something hidden inside the tumor must be causing the cancer. His culprit: a virus.

Rous' finding was met with such resounding disbelief that he soon abandoned the entire line of research. He returned to it 20 years later, still on the unpopular side of scientific opinion. More years passed, until Rous was finally vindicated with a Nobel Prize "for his discovery of tumor-inducing viruses" — 56 years after he began his work, in 1910.

Viruses exist at the border between living and nonliving, working their way into tissues and piggybacking on a cell's machinery to make copies of themselves. In the century since Rous' chicken studies, researchers have uncovered about half a dozen viruses that, while going about their sole mission of replicating, happen to trigger cancer. Some cancer viruses bear familiar names like HPV, known to cause cervical cancer, and hepatitis B and C, which lead to tumors in the liver. Others aren't so famous, including Epstein-Barr virus as a cause of non-Hodgkin lymphoma and two viruses known to cause tumors in people with severely repressed immune

systems. Yet scores of researchers are intrigued by the possibility of cancer viruses that haven't yet been discovered.

As of now, the official figure for the percentage of human cancers caused by viruses is around 20 percent — but most experts concede that number is largely an educated guess, accounting for known viruses behaving in predictable ways. "Thirty years ago, that number would have been 5 percent," says Robert Garry, a virologist at Tulane University School of Medicine in New Orleans. "It's a moving target. How high is it going to go? We don't know."

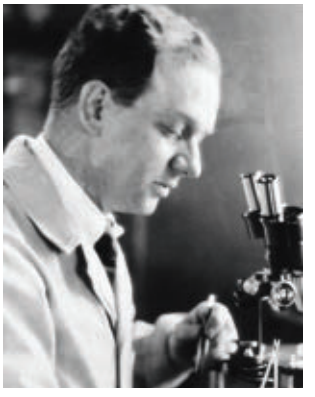
Soon, they may. Until recently, virus hunting involved painstaking detective work. But improvements in molecular technologies have made it easier to search for and study the behavior of snippets of nonhuman genes woven around otherwise normal threads of genetic material. In just the last eight years, a human pathogen discovery project housed at Washington University in St. Louis has found 40 new viruses. "We are huge walking bags of viruses," says Eain Murphy, a virologist at the Cleveland Clinic. "There are so many we don't even know what they do."

Not all will have a cancer connection. Yet considering the scope of cancer triggers that remain undiscovered — even in breast cancer, most women have no known risk factors aside from their age and sex — many researchers expect previously unknown viruses will be to blame for some cancers, or at least make otherwise sluggish tumors more aggressive.

Medical science has already compiled a long list of little-noticed viruses suspected of contributing to common malignancies, including cancers of the colon, skin, lungs, breast and brain. Recently, some types of skin cancer, and possibly other malignancies, have been linked to a powerful group of viruses called polyomaviruses, which are little more than free-range cancer genes.

New investigations also stand to finally settle old controversies — such as whether a virus can cause breast cancer — and ignite fresh ones. Already, some scientists are speculating whether lung cancer in nonsmokers may have some viral origin, either through human viruses or infections from animals. "The next decade promises to be an exciting era for the tumor virology field," researchers wrote last year in *Cancer Letters*.

Yet with better virus detection also comes a concern. If people are indeed walking bags of viruses, then every slice of tissue could hold countless false leads. As a case in point, researchers almost universally mention XMRV, a virus discovered in 2006 as a possible cause of prostate cancer. Six years and dozens of studies later, the general conclusion is that XMRV wasn't inciting human tumor cells, but was instead a case of laboratory contamination with a rodent virus.



Peyton Rous won a Nobel Prize in 1966 for discovering that a cancer in a chicken could be transmitted via a virus.

"You have to keep in mind the criteria for causality," says Dana Rollison, a cancer epidemiologist at the Moffitt Cancer Center in Tampa. Finding a virus inside a tumor opens questions that may take years to answer.

From rumor to tumor

Scientists have been interested in polyomaviruses since 1971, when they were found to infect humans. But the landmark report linking a polyomavirus to skin cancer was not published until 2008. In that study, appearing in *Science*, researchers from the University of Pittsburgh Cancer Institute found that 80 percent of tumors from Merkel cell carcinoma, a rare but deadly form of skin cancer, contained a polyomavirus now named Merkel cell polyomavirus, or MCV for short. In May, those researchers and others reported in *Science Translational Medicine* that an experimental drug targeting the virus appeared to stop the cancer from growing.

"Of all the viruses that might have a plausible link to cancer, none have a more deadly gene than polyomaviruses," says Richard Boland of the Baylor Research Institute in Dallas. Healthy tissues can start down the path to cancer if a gene producing something called T antigen turns on, taking mechanisms that naturally suppress cancer growth offline. The "T" stands for transforming. A polyomavirus "is essentially the T antigen gene with a bunch of packing and assembly material," Boland says.

MCV may even have a role in squamous cell carcinoma, the second most common form of skin cancer in the United States. Squamous cell carcinoma arises from cells making up the upper layers of the skin, and while not as dangerous as melanoma because it is less likely to spread, it can be deadly in some cases.

It's known that ultraviolet light is a risk factor for skin cancer, but that doesn't explain why so many people exposed to sunlight don't get cancer, or why the cancers can sometimes appear on skin that rarely sees the light of day. In recent studies, Rollison has found MCV in 38 percent of squamous cell tumors.

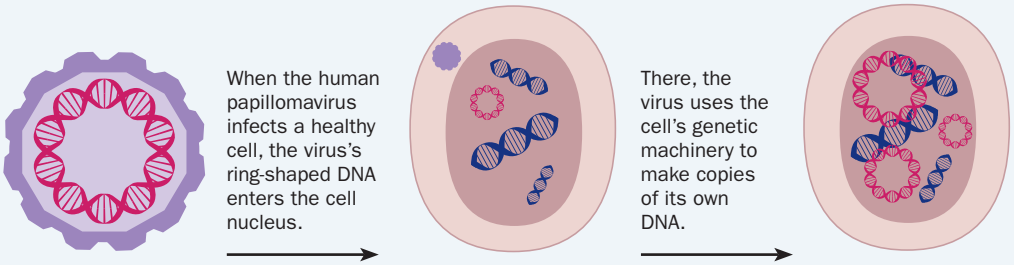
Patients with squamous cell carcinoma who were infected with the Merkel cell virus were about twice as likely to have antibodies for MCV as were people who didn't have cancer, Rollison and colleagues reported in January in *Cancer Epidemiology, Biomarkers & Prevention*. That's a sign that the bodies of the cancer patients had been fighting an active infection. One of the criteria for linking a virus to cancer is that at some point in the life of the cell, the virus has to be actively replicating itself, creating an infection that would prompt the immune system to react.

The support for MCV's role in squamous cell tumors "is compelling, but it's not definitive," says Rollison. "The piece that is really missing is prospective data,

SCIENCE SOURCE

A cell co-opted

Once it infects a human cell, a virus uses the cell's machinery to replicate its own genetic material. This co-opting can also insert cancer-promoting genes into human chromosomes, as occurs with human papillomavirus, or HPV.



showing that the virus was there before the cancer."

Polyomaviruses are emerging as a possible risk factor in other cancers, not just those of the skin. Boland is investigating whether a polyomavirus called John Cunningham virus, or JCV, might trigger some colon and anal cancers. JCV is common, perhaps infecting as much as 90 percent of the adult population — a factor that can complicate virus-cancer investigations.

Because the virus needs coconspirators, like genetics, environmental conditions and tissue that is hospitable to infection, only a fraction of people who develop an active infection would get cancer. (That's also the case with other viruses: In June, Rollison and her colleagues reported in the *Journal of Infectious Diseases* that a practically ubiquitous virus of the skin might work synergistically with sunlight to promote nonmelanoma skin cancers.)

Estimates of how often JCV occurs in colon cancers vary considerably, from studies that find the virus in almost all colon tumors to those unable to find so much as a trace. As for anal cancer, last year Boland and colleagues published a study in *Cancer* suggesting that JCV is more common in anal cancers than is HPV, the cervical cancer virus, which is considered a risk factor. The analysis of 21 anal tumors found JCV in all of them, including nine that were clear of HPV.

Boland acknowledges that skepticism about JCV remains high, largely because only small numbers of virus particles appear to exist in full-blown tumors. This scarcity could be because the virus doesn't prompt the polyps to grow. In a hit-and-run kind of approach, it may only knock normal tissue into the early steps of cancer. If JCV is necessary only to make healthy tissue blossom into a polyp, the virus could be long gone by the time the cancer shows itself.

JCV could also be aiding and abetting the tumor process farther down the line, not just at the beginning. Boland and colleagues published experiments in 2009 in *PLoS ONE* suggesting that infection with JCV increases the likelihood that tumors will spread. Work remains to show that patients with colon cancer have antibodies to the virus, and Boland acknowledges that he could be proved wrong. "I made a decision very early on not to get breathless about this," he says.

A woman's odds of getting breast cancer greatly depend on where she lives.

Of mice and women

Among other researchers with sober expectations are those who have engaged in a controversial, decades-long pursuit of a breast cancer virus. Seven laboratories have found evidence supporting the idea that a virus could trigger human breast cancer, according to a 2009 report in the *Journal of the National Cancer Institute*.

A mouse version of a breast cancer virus was discovered in the 1930s, and since then the idea of a human counterpart has gone in and out of scientific favor. The mouse version, known as mouse mammary tumor virus, or MMTV, is passed from mother to offspring through breast milk.

Some of the most intriguing hints of an infectious cause in humans come from how the basic geography of the disease syncs with prevalence of MMTV. A woman's odds of getting breast cancer greatly depend on where she lives. Worldwide, the odds of getting cancer vary, with African and Asian women having a fraction of the risk that European and North American women do. Plus, a woman who moves from a region with a low incidence of breast cancer to a higher one appears to acquire the risk level of her new home.

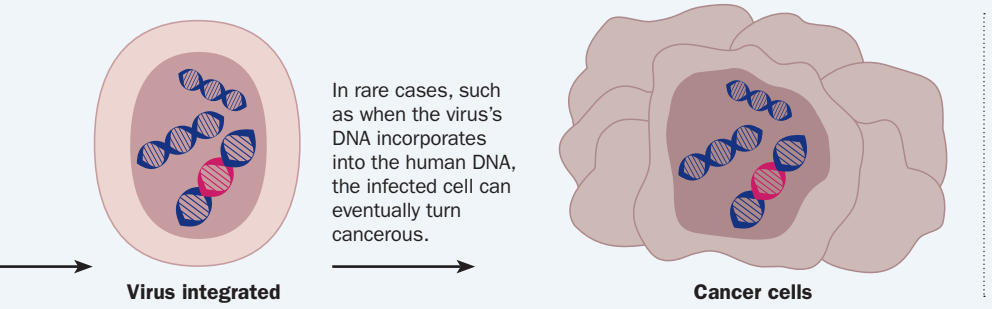
"In Europe and North America, the mice have a lot of mouse mammary tumor virus. In Asia, where they have the Asian house mice, it's very, very difficult to find it," says Garry of Tulane. Women in North America have a risk of breast cancer up to three times as high as women in Asia. The question is whether the mouse version has been able to remodel itself for human tissue.

Garry believes it might have. From laboratory samples at Tulane, he found evidence of a separate human mammary tumor virus. But when Hurricane Katrina struck in 2005, the laboratory's breast tumor samples were lost, leaving him unable to conduct further studies. "I'm open-minded," he says. "Some of our studies pointed to the fact that there was a virus there."

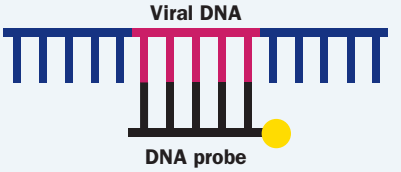
Later work has also been supportive. In 2007, a research team writing in the journal *Retrovirology* used updated genetic techniques to show, for the first time, evidence that MMTV could replicate inside human cells.

Many other scientists remain unconvinced that MMTV can adapt to people. "In my lab, we've not been able to infect human cells with the virus," says Susan

E. FELICIANO



A culprit nabbed
When looking for a virus-tumor connection, scientists can use probes that latch onto viral DNA, spotting the presence of this foreign genetic material in human cells.



Ross, a microbiologist at Perelman School of Medicine at the University of Pennsylvania in Philadelphia.

To show that a version of MMTV causes human cancer, she says, scientists must consistently demonstrate that the virus is able to enter human cells and use them as a personal Xerox machine. A woman's immune system must also show signs of fighting an active infection. Earlier studies have suggested such signs. But in 2006, Ross and colleagues from the National Cancer Institute reported in the *British Journal of Cancer* that, using more modern tests than in previous work, they were unable to detect antibodies to MMTV in a sample of women with breast cancer.

Up in the air

In addition to MMTV, other animal viruses can cause cancer, which makes them objects of scientific curiosity. In February, in *Zoonoses and Public Health*, epidemiologists from the University of Arkansas for Medical Sciences in Little Rock reviewed 60 studies of lung cancer risk among workers in the meat and poultry industry. That review found a 30 percent increased risk of lung cancer even after taking smoking into account. The researchers called for more careful study "so that the possible role of food animal oncogenic viruses in the occurrence of human lung cancer can be clearly defined."

There are already candidates. A virus called Jaagsiekte sheep retrovirus infects sheep and goats, and is the only known virus to cause lung cancer in any animal. Among those with a newfound interest in Jaagsiekte is virologist Robert Gallo from the University of Maryland's Institute of Human Virology, who was drawn to lung cancer after "too many friends died from cancer and they weren't smokers," he says.

While the vast majority of people with lung cancer have used tobacco, about 13 percent of cases occur in people who have never smoked. Cancer experts cite radon, secondhand smoke or other pollutants as possible causes, but the culprits have not been identified definitively. In addition to Jaagsiekte retrovirus, there's a possible association between lung cancer and HPV, researchers from the International Agency for Research on Cancer reported last April at a meeting of the American Association for Cancer Research.

For now, a lung cancer virus is little more than an idea among lots of ideas. But as someone who has been trying to uncover cancer-causing viruses for more than four decades, Gallo notes that locating viral genetic material in "human" DNA has never been easier, and new efforts stand to speed up the pace of tumor virology research.

In some ways, though, the field has never been more problematic, Gallo says. He, too, brings up the case of XMRV and prostate cancer, first found when researchers searched for viral culprits in the genetic instruction book of prostate cancer tissue.

It is great to have the power of genetic tools, Gallo says. "But you also have to have the power of thinking. What does it mean?" he says. "So you found a virus. It's the beginning of the beginning of a possibility."

Still, it is from possibility that discovery begins. As the late author Ray Bradbury once said, the best scientists start with the idea that anything is possible. ■

Viral origins Over the last half-century or so, scientists have linked a number of viruses to cancers in humans. Around 20 percent of human cancers are now thought to have a viral culprit. That portion is expected to grow as researchers use improved techniques to uncover more viral genetic material in tumor cells.

Virus	Linked cancers
Human papillomavirus	Cancer of the cervix, vulva, vagina, penis, anus, oral cavity, oropharynx and tonsil
Hepatitis B	Liver cancer
Hepatitis C	Liver cancer and non-Hodgkin lymphoma
Epstein-Barr virus	Burkitt lymphoma, nasopharyngeal carcinoma, Hodgkin and other lymphomas
Human T-cell lymphotropic virus type 1	Adult T-cell leukemia and lymphoma
Kaposi's sarcoma-associated herpesvirus	Kaposi's sarcoma, primary effusion lymphoma
Merkel cell polyomavirus	Merkel cell carcinoma (probable)

SOURCE: RONIT SARID AND SHOU-JIANG GAO/*CANCER LETTERS* 2011

Explore more

- Ronit Sarid and Shou-Jiang Gao. "Viruses and human cancer: From detection to causality." *Cancer Letters*. June 28, 2011.

Behind the Higgs

A primer on a long-sought boson

For decades, physicists have been promising the world that it is worth the money to build enormous machines, costing billions of dollars, to shock empty space into revealing an exotic particle called the Higgs boson. After years of false starts and frustration, hints and hopes, the Higgs has finally been found at the Large Hadron Collider outside Geneva (see Page 5). It's a cause for celebration — and for explanation, of what the Higgs is and why it matters. — *Tom Siegfried*

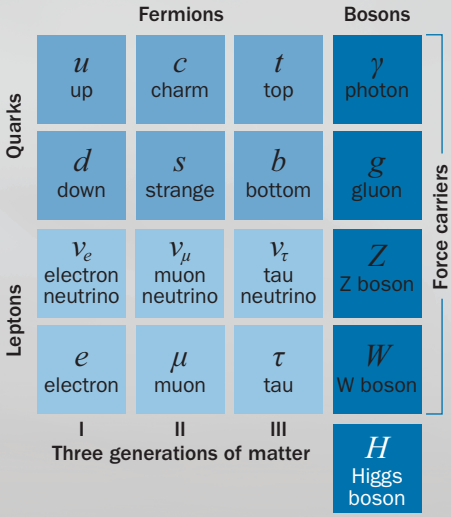
The Higgs' cosmic purpose

Ever since scientists figured out that the universe began with an explosive bang, some of them have wondered how the initial incendiary chaos cooled into a cosmic palace of intricate structure. Galaxies full of stars and planets built from complex atoms somehow congealed out of the Big Bang's formless fireball. As physicists developed equations to describe the basic particles of matter and the forces governing them, one aspect of reality seemed missing: None of the particles would possess any mass.

In 1964, physicist Peter Higgs of the University of Edinburgh proposed that the infant universe (as in, perhaps a trillionth of a second old) experienced a cosmic hiccup — technically, a phase transition. In much the way an iron bar can suddenly become a magnet when cooled below a certain temperature, space itself acquired a new feature. Instead of a magnetic field, space was filled with a new forcelike field — since named for Higgs.

Other physicists worked out similar scenarios at about the same time, and later work showed how the Higgs phase transition could explain the distinct identities of two of nature's basic forces: electromagnetism and the weak nuclear force.

The Standard Model



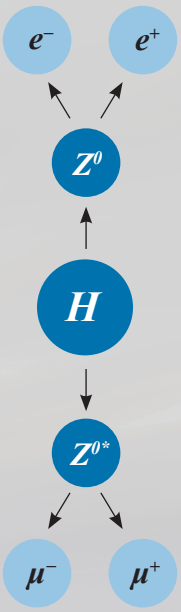
Before the Higgs field appeared in the vacuum, those two forces were one and indivisible. And all particles of matter and force carriers within the mathematical apparatus known as the standard model (shown) were massless. Afterward, particles of light, or photons, remained massless and propagated the force of electromagnetism. Weak force particles, and matter particles such as electrons and quarks, became massive.

Scientists use various analogies to explain what happened. Basically, particles moving through space are impeded by the presence of the Higgs field to a greater or lesser degree. Some, like photons, are not held back at all and therefore have no mass. But other particles chug through the Higgs field like bowling balls through mud, meeting resistance to their motion. Such resistance to motion (or more precisely, change in motion) is the very definition of inertia, which in turn is the very definition of mass.

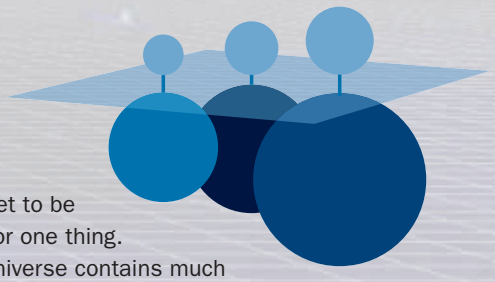
Shake that field

With the Higgs field, physicists completed the standard model, which accurately describes the behaviors of all known particles and forces (except gravity). But proof of the Higgs field's existence was lacking. Only one surefire method could verify the validity of the standard model: discovery of a particle—the Higgs boson—created out of the stuff of the Higgs field.

In the standard model, all particles are something akin to knots in an underlying field that are generated by a sufficient concentration of energy. Various clues hinted that the Higgs boson's mass was very large, meaning a lot of energy would be needed to make one. So the Large Hadron Collider was designed to collide protons with energies exceeding several trillion electron volts. A Higgs boson created in such collisions would exist too briefly to detect. But its decay would give birth to detectable particles, and that's how the physicists at the LHC discovered it. Detectors at the LHC recorded products of various Higgs decay paths, including one (shown) creating Z bosons that produce four leptons (such as an electron, positron, muon and antimuon) and another path that ends up producing two photons. Analyzing this debris indicated that the mass of the Higgs boson itself is about 125 billion electron volts, equivalent to the mass of 133 protons.



Collisions continue



While the Higgs fills out the standard model, the quest to understand matter and energy doesn't now end. Gravity has yet to be incorporated into the picture, for one thing. And scientists know that the universe contains much more matter than the standard model can accommodate. Entirely new species of particles are needed to explain invisible "dark matter" in space, which exists in quantities vastly greater than ordinary matter. Such particles may also be discovered at the LHC. Theorists suggest that these particles may be described by a mathematical framework known as supersymmetry, which posits a shadow partner particle for every known particle (illustrated). If so, more than one Higgs field would permeate space, and the Higgs boson may turn out to have several relatives awaiting discovery.

BACKGROUND ART: NICOLLE RAGER FULLER; THREE INSETS: T. DUBÉ

Nature's secrets foretold

Higgs discovery celebrates math's power to make predictions about the real world

By Tom Siegfried

By now, all aficionados of physics news — and quite a few people who don't know physics from phonics — have heard about the discovery of the Higgs boson. It's the biggest news in physics ever tweeted. And it came after a long wait. For more than three decades, the Higgs has been physicists' version of King Arthur's Holy Grail, Ponce de León's Fountain of Youth, Captain Ahab's Moby Dick. It's been an obsession, a fixation, an addiction to an idea that almost every expert believed just had to be true.

But despite years of searching, using the most complex machines ever built on the planet, the Higgs remained as elusive as a World Series ring for a Chicago Cub. Until now. Physicists at CERN's Large Hadron Collider have finally established the existence of a new particle, weighing in at a mass of about 11 dozen protons, matching the description of the fugitive Higgs. "We're reaching into the fabric of the universe at a level we've never done before," says physicist Joe Incandela, spokesman for one of the teams reporting the discovery.

Asked why the Higgs boson is so important, most physicists reflexively respond that it's a piece of the cosmic substance that endows elementary particles with mass. That perhaps, to some, sounds a bit underwhelming — just another culprit to blame for the obesity epidemic. But the Higgs' importance should be expressed more dramatically: The Higgs makes physical reality the way it is, with atoms, chemical reactions and life. No Higgs, no molecules. No planets. No people.

Strictly speaking, it's better to say that without the Higgs, something even more exotic would have to do its job. That job, in physics speak, is "electroweak symmetry breaking." In the universe's earliest picoseconds, electromagnetism was a component of a more primordial "electroweak" force, incorporating what's now called the weak force (known for its role in radioactivity). Equations describing the electroweak force are symmetric — that is, they describe electromagnetism and the weak force as equals. But somehow, the weak force split from electromagnetism. In other words, this mathematical symmetry between electro- and weak forces was "broken."

Symmetry in nature's laws is not optional; it ensures that the laws work the same for everybody, no matter where they are or how they move. But the math's symmetry can be disrupted by physical processes. That's what the Higgs does: It puts the universe on course to create reality's complexities.

"In seeking the agent of electroweak symmetry breaking, we hope to learn why the everyday world is as we find it: why atoms, chemistry, and stable structures can exist," writes theoretical physicist Chris Quigg of Fermilab.

Mathematically, the Higgs boson is a consequence of equations describing a field of force, the Higgs field. Visually, it's not so easy to describe. Like the magnetic field around a magnet, the Higgs field exerts its influence without being visible.

Also like a magnetic field, the Higgs field's strength falls to zero when the temperature is too high. (Heat an iron bar magnet above 770° Celsius, and the magnetism vanishes.) So at the birth of the universe in the Big Bang, when temperatures exceeded a million billion trillion degrees, the Higgs field did not distinguish itself. It and everything else that the universe was destined to contain existed within an undifferentiated primordial fireball of explosive energy.

You could think of the infant cosmos as a huge container of nothing but hot steam. As the steam cools, eventually some droplets of water will form. Sooner or later some ice crystals emerge as well. It is, of course, all the same stuff (H_2O), simply boiled into a featureless form. In a similar way, the featureless newborn universe was all the same stuff — in this case, stuff that would become all the species of the standard model of particle physics. Quarks (various flavors and colors),

leptons (electrons and their cousins), gluons (to hold quarks together), bosons (for transmitting forces), everything that makes up everything in the world today was waiting to materialize like ice out of the primordial steam. And, like pure radiation, all these entities possessed only energy, no mass.

As the universe expanded and cooled, the particles of matter — a roster using up most of the letters in the Greek alphabet — began to appear. Quarks congealed out of the primordial haze, announcing the arrival of the strong nuclear force, no longer indistinguishable from other forces. But still these particles possessed no mass. Like smooth steel balls rolling over perfectly slick ice, nothing resisted their motion. Resistance to motion is inertia. Inertia is the hallmark of mass. No resistance, no inertia, no mass. In a world without mass, protons and neutrons would form, but electrons would refuse to orbit them. So atoms and molecules could not exist. None of the features of the familiar world would appear.

Less than a nanotick of the cosmic clock later, though, the grandest event in the universe since its birth changed the game. Higgs stuff condensed into a new form. Just as a sufficiently low temperature permits an iron bar's magnetism, a sufficiently cool universe turned the Higgs field into something that matter had to contend with. Rather than skimming effortlessly over ice, particles now had to swim through a thick ocean, facing resistance to their motion, thereby acquiring mass. And the universe was never to be the same again.

Peter Higgs predicted the existence of the newly discovered particle that bears his name.

In essence, the Higgs field split the electroweak force's personality. Photons, carriers of electromagnetic influence, were oblivious to the newly palpable Higgs field, and so continued on in their merry massless way, letting there be light. Transmitters of the weak part of the electroweak force, two W particles (one positively charged, one negative) and the neutral Z particle, felt the Higgs force dramatically. While the photon remained massless, for the W's and the Z flying though space became more like swimming through molasses. Similarly, quarks felt the Higgs' presence, also acquiring mass (although not in precisely the same way).

Particles have different masses because they interact with the Higgs field to different degrees. At a nontechnical level, physicists sometimes speak of the field as a flock of paparazzi. Massive particles are like Hollywood celebrities — the paparazzi impede their path. The more famous, the more paparazzi get in the way, so the greater the resistance (or the mass). B actors (lightweights) pass through the paparazzi crowds much more quickly. Massless photons cannot even be linked to Kevin Bacon. They are invisible to the paparazzi.

At least, that's the story physicists had been telling themselves. It's so compelling, mathematically and aesthetically, that most experts believed that nature had to follow the script. But doubts nagged many who knew history. An imponderable substance filling all of space, responsible for fundamental physical phenomena? A good description of the ether, the 19th century version of the Higgs field. It turned out that the ether didn't exist. Some feared the same fate for the Higgs.

But this time came success. Smashing protons at more than 99.999999 percent of the speed of light infused the Higgs field with trillions of electron volts of energy, enough to shake loose the field's signature particle, the Higgs boson. While its life is short, the daughter particles of the Higgs' decay register their births in the Large Hadron Collider's detectors, and the Higgs' brief presence can be deduced, confirming the reality of its field.

Scottish physicist Peter Higgs conceived of such a field in 1964 and predicted the particle's existence. He wasn't the only physicist of that era to devise similar mathematical scenarios. Still others showed how the Higgs idea could orchestrate the breaking of electroweak symmetry. All those participants in elucidating the Higgs' role in reality shared a common prescience, an ability to see deeply into nature through the lens of mathematics.

Their success illustrates a further meaningfulness of the Higgs discovery: It validates the scientific enterprise as a way of knowing nature. Somehow, humans fiddling with squiggles on paper figured out what you would find if you spent billions of dollars on a machine to create temperatures of a million billion degrees. Scientists figured out one of nature's deepest secrets just using their heads.

"This is an enormous triumph for mathematical methods to make predictions for things in the real world," says physicist Brian Greene. "This Higgs particle has been a hypothetical mathematical symbol in our equations for 40 years."

During that time most physicists came to believe in the Higgs boson's existence as an article of scientific faith. Without it, something was desperately wrong with the entire framework of science's understanding of the universe. Had the Higgs boson not materialized when the Higgs field was properly probed, it would have been as though Voldemort had succeeded in killing Harry Potter.

Harry triumphed, though, and so has the Higgs. Happily, however, the Higgs discovery is not the last chapter in nature's final book. There will be sequels. Physicists need more particles, not included in the standard set, to explain mysteries like the abundance of dark matter in space and how gravity fits in with the rest of nature's forces. And the Higgs boson now discovered may merely be one member of a much larger Higgs family, with cousins performing various other important jobs in constructing the universe.

"We're on the frontier now, we're on the edge of a new exploration," says Incandela. "Maybe we see nothing extraordinary ... or maybe we open up a whole new realm of discovery." ■

T. SIEGFRIED

Trinity: A Graphic History of the First Atomic Bomb

Jonathan Fetter-Vorm

Others have already written the atomic bomb's biography, and Fetter-Vorm doesn't add new insights or historical scholarship. But he does provide a remarkably accessible — and frankly, beautiful — introduction to the events that ushered in the Atomic Age.

His graphic novel can't be as thorough as the Pulitzer Prize–winning *The Making of the Atomic Bomb* by Richard Rhodes. Still, the thin hardcover presents the key events and introduces the major players. History is distilled into a series of snapshots in comic-book framing, featuring excerpts from notable conversations between scientists, generals and politicians.

In one drawing, a scientist asks, "Can it be done?" Juxtaposed is a scene of charred Japanese corpses and another scientist asking, "Should it be done?"

The matter-of-fact text largely avoids taking sides or answering such questions. But the art is commentary in itself — not on the bomb's impact on humankind, but on the majesty of the physics that made such a device possible. Illustrations of the subatomic world explain everything from the research that led to the first fission reactor to the radiation sickness that poisoned residents of Hiroshima and Nagasaki.

The main protagonist here isn't a human; it's the atom. While Rhodes ends the main body of his book on a note of fear — a Japanese doctor who wakes short of breath after a nightmare — Fetter-Vorm's work closes with a meditative reflection on matter and energy. On the final page, radiation streams from a desert west of Los Alamos. The force of nature behind this radiation is "as innocent as an earthquake ... as oblivious as the sun," he writes. "It will outlast our dreams."

— Devin Powell

Hill and Wang, 2012, 154 p., $22

The Violinist's Thumb

Sam Kean

Early in the 20th century, German biologist Hans Spemann separated two cells of a salamander zygote using a strand of his daughter's hair. His experiment produced two fully formed amphibians, demonstrating that each cell contains the full genetic blueprint to build a living thing, not the partial instructions that scientists had previously supposed.

Why he used the child's hair isn't clear, science writer Kean notes, but "probably the baby's hair was finer."

In Kean's history of DNA, each chapter is loosely organized to address questions about humans' genetic past and future. He pays tribute to genetics' key players and major milestones, including Watson and Crick, Mendel and the researchers who raced to draw up the human blueprint ("blitzkrieg sequencing," Kean calls it) during the Human Genome Project.

But Kean's real knack is for digging up strange details most textbooks leave out. So in addition to the great achievements, this is also the story of how scientists express artistic sides with sculptures crafted from DNA, what genetic disorders Darwin (and Lincoln, Kennedy and Tutankhamen) might have had and why a genetic adaptation in polar bears means it's a bad idea for humans to snack on the bears' livers. It's also about violinist Niccolò Paganini and how his genes gave him both remarkably flexible hands and medical issues that left him unable to perform.

More than an assortment of trivia, the book is an engaging history. After all, Kean quips, "the story of DNA has effectively replaced the old college Western Civ class as the grand narrative of human existence." *— Allison Bohac*

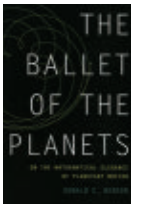
Little, Brown & Co., 2012, 317 p., $25.99

Moral Origins

Christopher Boehm

An evolutionary anthropologist looks back through human evolution for clues to how groups of hunter-gatherers developed altruism and generous behaviors.

Basic Books, 2012, 418 p., $28.99



The Ballet of the Planets

Donald C. Benson

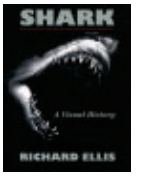
A mathematician describes the history of the science explaining planetary motion.

Oxford Univ., 2012, 178 p., $35

Legacy

Harry Ostrer

This history of the genetics of the Jewish people delves into the population biology and genetic diseases that tie the group together. *Oxford Univ., 2012, 264 p., $24.95*



Shark

Richard Ellis

The curator of a new shark exhibit at the Museum of Art/Fort Lauderdale in Florida presents a visual history of sharks and humans' fascination with them.

Lyons Press, 2012, 280 p., $24.95

Cracking the Egyptian Code

Andrew Robinson

The first English-language biography of linguist Jean-François Champollion describes his quest to decipher hieroglyphs using the Rosetta Stone. *Oxford Univ., 2012, 272 p., $29.95*

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Shopping standards shift with age

In "When good moods go decisively bad" (*SN: 6/16/12, p. 10*), researchers assume that their 70-year-old study participants would be as interested as their 20-something counterparts in finding up to 40 prices on 60 products in an Internet shopping exercise. When the septuagenarians fail to choose the cheapest product, the researchers infer that the happy elderly may make poor decisions. Perhaps instead, the happy oldsters make a quick, acceptable decision rather than waste time making a marginally more perfect one.

Kevin Stevenson, Port Townsend, Wash.

Bettina von Helversen, one of the study researchers, responds that elderly volunteers reported more interest in getting good deals on the task than younger volunteers did, although there's no guarantee that both groups were equally motivated by financial rewards. Older adults probably did favor good-enough decisions, but because they experienced more positive feelings than the younger group, not because of a lack of motivation, in her view. —Bruce Bower

Birds forage intelligently

Having been there, I recognized the map of Kerguelen Island in "Birds forage with fractal-like flight" (*SN: 6/2/12, p. 12*) and looked it up on Google Maps. The flight paths shown closely follow seafloor topography, with concentrations centered on readily identifiable subsurface features. As an oceanographer, I have casually observed that gooney birds like to accompany our ship the *RV Argo*, using the aerodynamics of the ship's passage to soar effortlessly and feasting every time our messman empties meal waste. I suggest the birds behave in a much more well-informed manner, responsive to their local environment, than portrayed in the article.

Leandra Vicci, Silk Hope, N.C.

Send communications to: Editor, Science News, 1719 N Street, NW, Washington, D.C. 20036 or **editors@sciencenews.org**. Letters subject to editing.

The Science Life

To watch a video recorded by a tornado probe, visit **www.sciencenews.org/people_tornado**

Storm chaser Tim Samaras snapped this tornado tearing across south-central Kansas in 2004. He likens the sound of a tornado to the rush of a powerful waterfall.

Calm, with an eye on the storm

When Tim Samaras and his crew show up in a small town, their cars bristling with anemometers and other weather instruments, the welcome isn't always warm. "There are locals who think we are bringing the weather," says Samaras, 54. "One or two have even asked us to leave."

True, it seems like wherever Samaras ventures each spring, tornadoes follow. But that's just a sign of the storm chaser's knack for staying a step ahead of his prey. "We cannot go to Google and order up a tornado," he says. "We have to go find it ourselves."

This year during peak tornado season, Samaras and his colleagues spent March through June chasing twisters across the Midwest, zigzagging up to 1,000 miles a day. The chase is a labor of love for the engineer, who works independently and recruits outside funding to help pay for his seasonal occupation.

He began chasing storms as a child, bicycling after thunderheads as they blew eastward from his Colorado home. Today, Samaras doesn't so much chase as get ahead of as many tornadoes as possible. When he can, he drops a steel-encased probe of his own design right in the tornado's path. While he flees, the squat, conical probe rides out the storm, its shape designed to use the wind to keep it pinned in place. The probe records the pressure, humidity, temperature, wind speed and direction within the swirling core. Those measurements give Samaras rare insight into ground-level tornado dynamics — right where twisters wreak their havoc. Crucially, it's also a region unseen by ground-based radar.

"The only way you can measure how powerful and chaotic those winds are is with in situ instruments," Samaras says. "That is the piece of the puzzle I bring to the scientific table." His probes once measured howling 100-mile-per-hour winds (160 kilometers per hour) at ankle height as well as a record-setting 100-millibar drop in atmospheric pressure.

Direct hits are few and far between, though. Even though 1,200 tornadoes lash the United States each year, Samaras has so far directly measured the vortices of just 12. "If you don't get out in the field and chase a lot of mediocre opportunities, you have an excellent chance of not seeing anything," he says. — *Andrew Bridges*

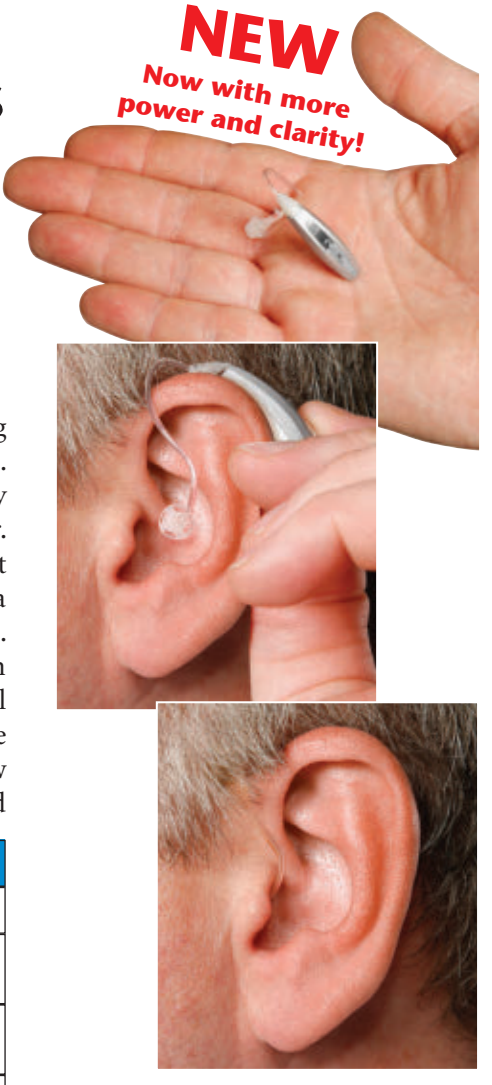
Tim Samaras holds one of the "turtle" probes that he designed to record pressure, wind speed and other conditions inside tornadoes.

FROM TOP: T. SAMARAS; PAT PORTER

The invention of the year is great news for your ears

Perfect Choice HD™ is easy to use, hard to see and costs far less… it's like reading glasses for your ears™!

New Personal Sound Amplification Product is an affordable alternative



Over the years, technology has made the way we live easier, safer and more convenient. In many cases, it's even made many products more affordable… (remember how much the first VCR used to cost?). Unfortunately, the cost of hearing aids never seemed to come down. Now, a new alternative has been invented… it's called Perfect Choice HD™.

"Reading glasses for your ears"

Perfect Choice HD is NOT a hearing aid. Hearing aids can only be sold by an audiologist or a licensed hearing instrument specialist. In order to get a hearing aid, you had to go to the doctor's office for a battery of tests and numerous fitting appointments. Once they had you tested and fitted, you would have to pay as much as $5000 for the product. Now, thanks to the efforts of the doctor who leads a renowned hearing institute, there is Perfect Choice HD. It's designed to accurately amplify sounds and deliver them to your ear. Because we've developed an efficient production process, we can make a great product at an affordable price. The unit has been designed to have an easily accessible battery, but it is small and lightweight enough to hide behind your ear… only you'll know you have it on. It's comfortable and won't make you feel like you have something stuck in your ear. It provides high quality audio so sounds and conversations will be easier to hear and understand.

Perfect Choice HD feature comparison

	Perfect Choice HD	Others
Lightweight and Inconspicuous	YES	Some
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