An aerial view of the Colorado River delta as the river once again meets the Sea of Cortez.

A River Resurrected

On May 15, through the window of a propeller plane, conservationist Francisco Zamora witnessed history in the making. Below, he watched a finger of water creep down the dry Colorado River channel and meet the tide in the Sea of Cortez.

It was the first time the 1,450-mile river had been reunited with its natural terminus in more than 60 years (aside from a brief trickle during the unusually wet 1990s). Farms and cities siphon most of the river's water before it reaches Mexico, but on March 23, under a binational agreement, U.S. and Mexican officials unleashed an eight-week "pulse flow" from a small dam on the border to help restore the delta. No one knew, though, whether the water would make it that far downstream.

While the 105,000-acre-foot surge amounted to less than 1 percent of the river's average flow, the ecosystem is showing new signs of life. (One acre-foot of water is enough to supply two homes in the Southwest for about a year.) "The response of the birds is pretty amazing," says Zamora, director of the Sonoran Institute's Colorado River Delta Legacy Program. "Just adding water really enhances the habitat."

Scientists and officials are exploring ways to keep the water coming. "We could potentially reconnect the river with not a lot of water," Zamora says. "The pulse flow showed it can be done." – APRIL REESE

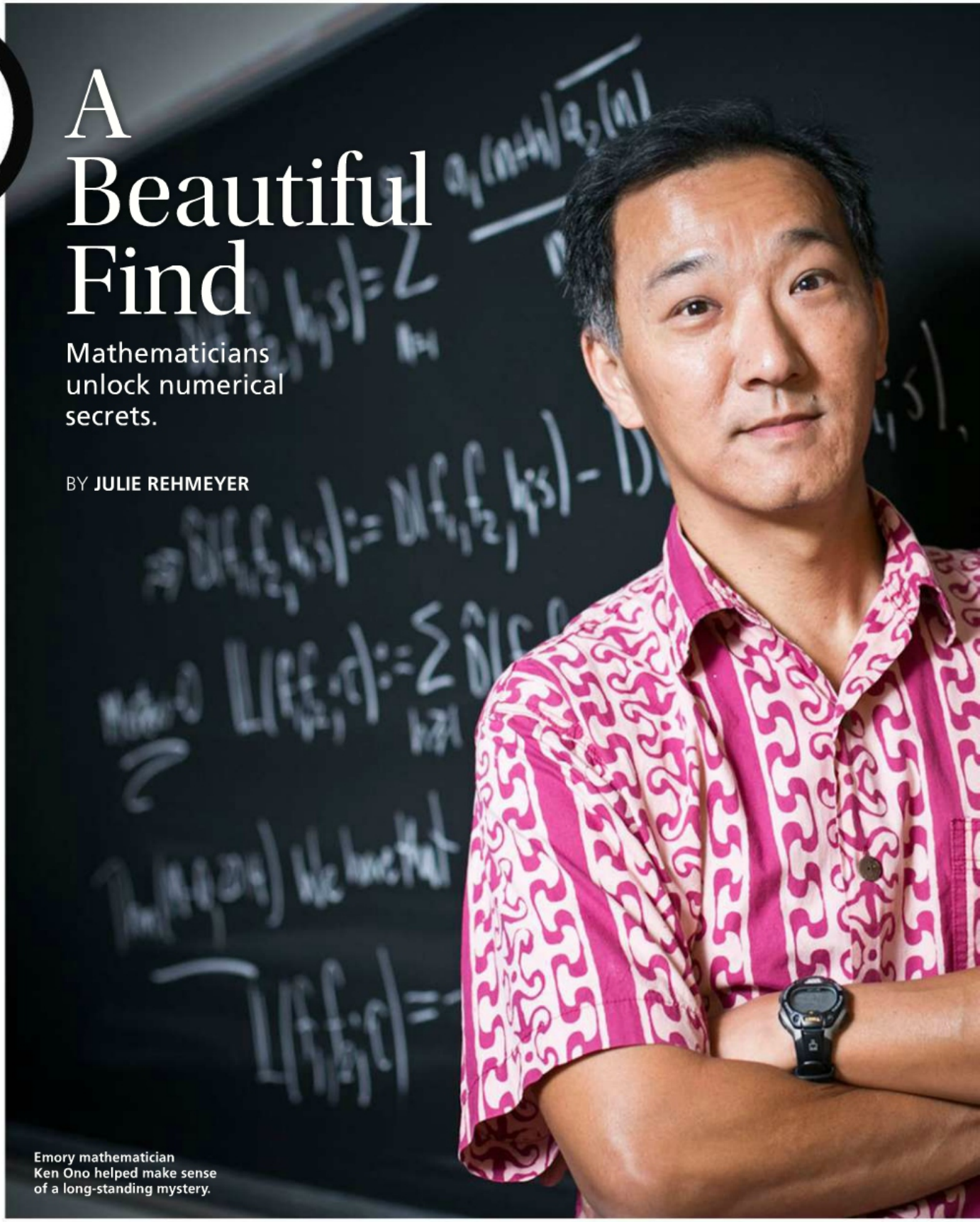
PHOTOS: PETER MCBRIDE. MAP: COURTESY U.S. DEPARTMENT OF THE INTERIOR, BUREAU OF RECLAMATION; ROEN KELLY/DISCOVER

15

A Beautiful Find

Mathematicians unlock numerical secrets.

BY **JULIE REHMEYER**



Emory mathematician Ken Ono helped make sense of a long-standing mystery.

LEFT: EMORY UNIVERSITY. RIGHT: THE GRANGER COLLECTION,NYC

Q&A

Last summer, Ken Ono of Emory University became a minor mathematical celebrity when he, along with collaborators Michael Griffin and Ole Warnaar, discovered four infinite families of identities — mathematical formulas involving variables (like x or y) that are true regardless of the values of those variables. (For example, $(a * b)^x = a^x * b^x$.) The new identities are generalizations of two specific ones first found by the great mathematicians Leonard Rogers and Srinivasa Ramanujan in the early 1900s. The finding is a milestone in mathematics.

What led to your interest in the Rogers-Ramanujan identities?

I first learned about them from a famous story. In 1913, the great English mathematician G.H. Hardy received a letter from an unknown, uneducated clerk from India: Srinivasa Ramanujan. Attached were nine pages of mathematical formulas.

A lot of them were well known, and some wrong, but a few were gems, especially two. Hardy said that they must be true because no one would have had the imagination to invent them.

What were these special identities of Ramanujan's?

They're slightly more complicated versions of a beautiful "continued fraction":

First take 1+ 1, or 2.

Next, replace the last 1 with $\frac{1}{1+1}$ to get $1+\frac{1}{1+1}$, or 1½.

Now do it again: $1+\frac{1}{1+\frac{1}{1+1}}$, which gives 1⅔.

If you do that forever, you get the golden ratio, which is defined as: $\frac{1+\sqrt{5}}{2}$

Ramanujan evaluated two other continued fractions in this way. It was largely because of those that Hardy, the professional, and Ramanujan, the amateur genius, ended up collaborating to invent some of the most important mathematics of their day.

Indian mathematical prodigy Srinivasa Ramanujan.

How did Ramanujan come up with those identities that captivated Hardy?

Ramanujan had a secret device: two more identities that he had discovered, which later came to be called the Rogers-Ramanujan identities. He plugged specific numbers into those two identities.

What did you discover about the Rogers-Ramanujan identities?

Griffin, Warnaar and I found a framework that shows why they're true and structurally what makes them tick. They turned out to be two golden nuggets that suggested the existence of a whole mother lode of identities out there. And we showed that they can easily produce numbers mathematicians call "algebraic," which are rare, beautiful numbers akin to the golden ratio.

Why is it important?

The Rogers-Ramanujan identities are tied to a lot of deep mathematics. So this larger framework for them will open up new mathematical territory.

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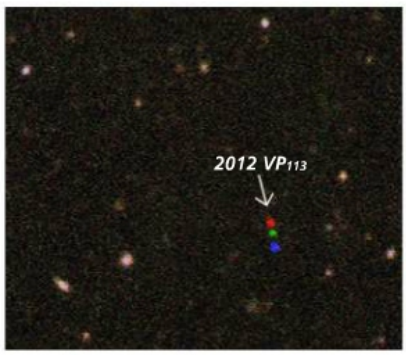
Sedna, shown in this artist's visualization, was once thought to be the only outlier of our solar system. Now 2012 VP_{113} joins it.

New Dwarf Planet Redefines Solar System

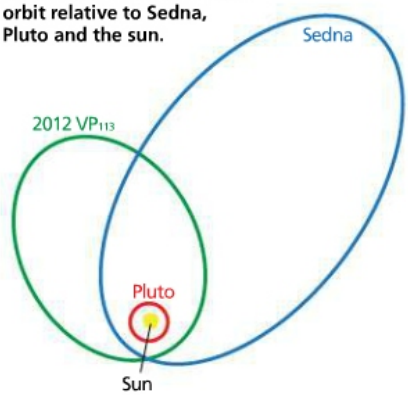
It's not every day we redraw the map of the solar system. With the March discovery of minor planet 2012 VP_{113} orbiting the sun beyond Pluto, astronomers added a new world to the planetary rolls — and redefined the edges of our cosmic neighborhood.

The solar system's farthest major planet, Neptune, is only 30 astronomical units from the sun. (An AU is the average Earth-sun distance, 93 million miles.) Beyond that, at 30 to 50 AU, lies the Kuiper Belt and its minor planets, including dwarf planet Pluto. Before discovering 2012 VP_{113} — soon nicknamed "VP" or "Biden," after the U.S. vice president — astronomers thought only tiny Sedna occupied the empty stretch beyond 50 AU. Now they know it's not alone.

Sedna's perihelion, or closest solar approach, is 76 AU; VP has a perihelion of 80 AU. The newly found world is about 300 miles wide, likely enough for gravity to shape it into a sphere and thus be considered a dwarf planet (though still about five times smaller than Pluto). Its discovery suggests hundreds of similar worlds may lurk in this distant part of the solar system. More tantalizingly, minor perturbations in the orbits of the farthest known objects suggest a massive "super-Earth" major planet might lurk about 250 AU away. — BILL ANDREWS



The red, green and blue dots above depict the movement of 2012 VP_{113}. Researchers added color for visibility. The illustration below shows its orbit relative to Sedna, Pluto and the sun.



FROM TOP: NASA/JPL-CALTECH; SCOTT S. SHEPPARD/CARNEGIE INSTITUTION FOR SCIENCE; ALISON MACKEY/DISCOVER AFTER SCOTT SHEPPARD

The First Designer Chromosome

17

In 2010, geneticist Craig Venter unveiled the world's first synthetic organism — a variant of a bacterium that causes infections in goats. In April, researchers took a step toward a much more useful synthetic microbe, synthesizing from scratch one of the 16 chromosomes of *Saccharomyces cerevisiae*, or baker's yeast.

Yeasts, like humans, are eukaryotes: They have complex DNA packaged in chromosomes and riddled with introns (pieces of DNA that don't contribute to the final protein) and "junk DNA" with no known purpose.

To simplify their task, researchers first searched the computerized genetic code of one chromosome — chromosome 3 — and deleted introns and junk DNA. They added in code to create 98 ready-made cutting sites, like perforations in a sheet of paper, throughout the chromosome. That way, future researchers can pop out various genes and study the effects. Eventually, getting rid of all the non-essential genes would result in a bare-bones yeast with the minimum number of genes possible.

That's important because yeast is a promising workhorse for synthetic biology. A slimmed-down genome will allow all the cell's available energy to go toward producing useful chemicals.

The synthetic chromosome, when inserted into a living yeast cell, functioned just like a normal one. That's good news, but the project to create a fully synthetic yeast genome has a ways to go: Chromosome 3 is just 2.6 percent of the cell's full genetic code.

But would fully synthetic yeast still be yeast at all? Srinivasan Chandrasegaran, one of the authors of the paper in *Science*, takes a pragmatic tack: "As long as it tastes like beer, it's yeast." — LISA RAFFENSPERGER

This synthetic yeast, made of a designer chromosome, is one step toward a fully synthetic version.

TECH APPLICATIONS

Yeast is already used as a miniature chemical factory in a variety of settings. Custom DNA could make these processes even more efficient.

Artemisinin: Drug manufacturer Sanofi is producing precursors to this anti-malarial drug in genetically modified yeast.

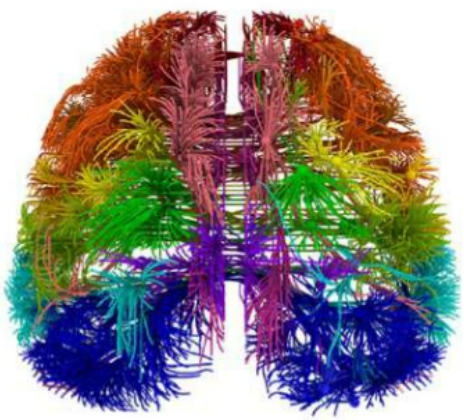
Beer: Brewers today use natural yeasts, but they could eventually design strains to produce exotic beers.

Vaccines: The hepatitis B vaccine is commonly made in modified yeast cells.

Biofuels: Researchers are modifying yeast to produce ethanol and biodiesel.

Mouse Brain Mega Map

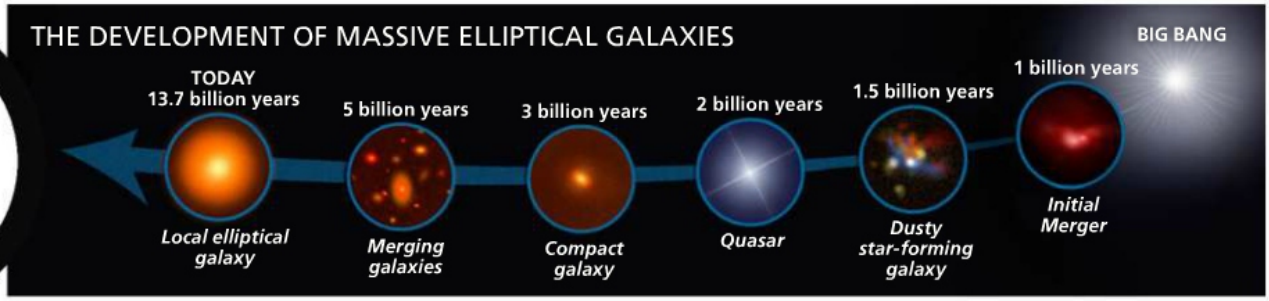
18



The tiny mouse brain is packed with more than 86 million neurons, each with more than 1,000 connections, clustered into different nodes — similar to a complex highway system. In April, researchers led by Hongkui Zeng of the Allen Institute for Brain Science in Seattle assembled the first road map of neural pathways — called a connectome — inside the mouse brain (left). It's the most comprehensive guide ever assembled of the mammalian brain. Scientists imaged more than 1,700 mouse brains (injected with a tracer virus) at resolutions less than a micrometer, or 50 times smaller than a human hair. They assembled the 1.8 petabytes of data — equivalent to running HD video continuously for 26 years — into a 3-D map. See it at **brain-map.org** — CARL ENGELKING

TOP: NYU LANGONE UNIVERSITY SCHOOL OF MEDICINE. BOTTOM: ALLEN INSTITUTE FOR BRAIN SCIENCE

19



The Lives of the Galaxies

If you'd never met a human, figuring out that babies and seniors are the same species might not be easy. Astronomers have to make such leaps all the time, matching snapshots of youthful galaxies with mature counterparts and filling in missing links.

Take the universe's most massive galaxies — blobby, indistinct ellipticals. Until this year, no one understood how they got so gargantuan. But in January, astronomers used optical and infrared telescopes to look back nearly to the beginning of the universe, just 1.5 billion years after the Big Bang, where they saw newborn ellipticals — ancient galaxies so dusty they're nearly invisible. In their early years, these galaxies formed stars a thousand times faster than the Milky Way does today, eating through their initial gas reserves in just 40 million years. After that, they grew slowly by mating with other galaxies, eventually snowballing into today's mature elliptical galaxies.

Now, 10 billion years later, they don't make new stars at all. Full of old, rose-colored suns, they are "red and dead." Theorists thought they'd become barren in their old age, lacking the cool gas that condenses into new stars. But in February, another team of astronomers discovered that some have plenty of cold gas — they just can't use it. These galaxies' supermassive black holes work against them, devouring nearby gas and exhaling powerful jets that either heat the remaining cold material or push it out of the galaxy entirely.

But not all the news this year focused on ellipticals; spiral galaxies showed up, too. This branch of the galactic family comes in different shapes: Some spirals have flat disks, while others are fat. In February, a third team of astronomers discovered the lifestyle difference: spin speed. As with pizza dough, the faster you twirl it, the thinner the crust becomes. Our own svelte galaxy spins at a speedy 600,000 mph.

Disks thin out or don't, stars form or don't, and galaxies grow gigantic but geriatric. As any astro-anthropologist would attest, making sense of our galaxy requires making sense of others that are younger, older, fatter, thinner and differently hued. — SARAH SCOLES

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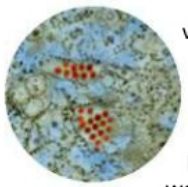
Dengue Vaccine Clears Major Trial Hurdle

Dengue, known in its most severe form as dengue hemorrhagic fever, is a potentially fatal mosquito-borne infection that afflicts up to 100 million people each year. It's become a leading cause of illness and death in tropical and subtropical regions around the world. But a new vaccine could reduce the disease's reach.



The dengue virus (red) in a tissue specimen.

In September, an international research team published much-awaited results of a clinical trial for the vaccine. In the study, which involved 20,875 Latin American children aged 9 to 16, the vaccine's efficacy was 60.8 percent, and it reduced the risk of hospitalization by 80.3 percent. Those results mirrored the findings of a smaller study by the same team published in July that involved about 10,000 children in five Asian countries. In that trial, the vaccine's efficacy rate was 56.5 percent, and it reduced cases of the severest form of dengue by 88.5 percent.

"This is an incredibly important milestone," says health economist Dagna Constenla of Johns Hopkins University, which is a member of the Dengue Vaccine Initiative, a research collaborative. Scientists have worked on dengue vaccines for years, but this one, created by French drugmaker Sanofi Pasteur, is the first to reach this advanced testing stage.

The virus that causes dengue has four types, and the vaccine appears more effective against some than others. Still, researchers say it holds great promise for combating the disease. Sanofi will seek approval of the vaccine in the next few months, and if all goes well, the drugmaker could begin marketing it by the end of 2015. — CHRISTIE ASCHWANDEN

TOP: NASA/ESA/S. TOFT (NIELS BOHR INSTITUTE)/A. FEILD (STSCI). BOTTOM: ROBIN TREADWELL/SCIENCE SOURCE

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Heavyweight Dino of the World

After four years of excavation and five years of study, *Dreadnoughtus schrani* debuted in September as a top contender for the largest land animal ever: 65 tons and 85 feet long, with a 37-foot neck and muscle-bound 30-foot tail.

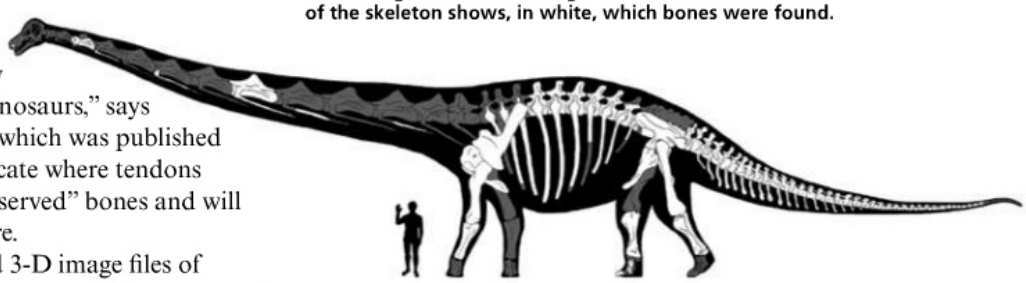
Paleontologist Kenneth Lacovara first spotted just a small patch of exposed bone one morning in February 2005 in Argentine Patagonia. Lacovara and fellow Drexel University researchers quickly returned, and by nightfall they had uncovered a 6-foot-long femur. "We knew immediately that we were looking at one of the largest known dinosaurs," says Lacovara.

Dreadnoughtus lumbered through fern-filled forests between 66 million and 85 million years ago, and it left an astonishingly complete fossil: Almost half of the bones, 145, were recovered. *Argentinosaurus*, presumed to be the largest titanosaur, is known based on just 13 bones.

"Until *Dreadnoughtus*, we could only guess at the body proportions of supermassive dinosaurs," says Lacovara, author of the study, which was published in *Scientific Reports*. Scars indicate where tendons attached to the "exquisitely preserved" bones and will allow analysis of its musculature.

The Drexel team has released 3-D image files of *Dreadnoughtus*, making it the first new species presented along with its open-access virtual skeleton. "Any scientist or kid in the world can, to a substantial degree, see just what we were seeing," Lacovara says. —ERIK NESS

Kenneth Lacovara stands amid the skeleton of the massive *Dreadnoughtus schrani* in Argentina. Below, a reconstruction of the skeleton shows, in white, which bones were found.



To download 3-D image files of the *Dreadnoughtus* discovery, go to tinyurl.com/Dreadnoughtus-images

FROM TOP: JENNIFER HALL; COURTESY KENNETH LACOVARA; LACOVARA, ET AL.

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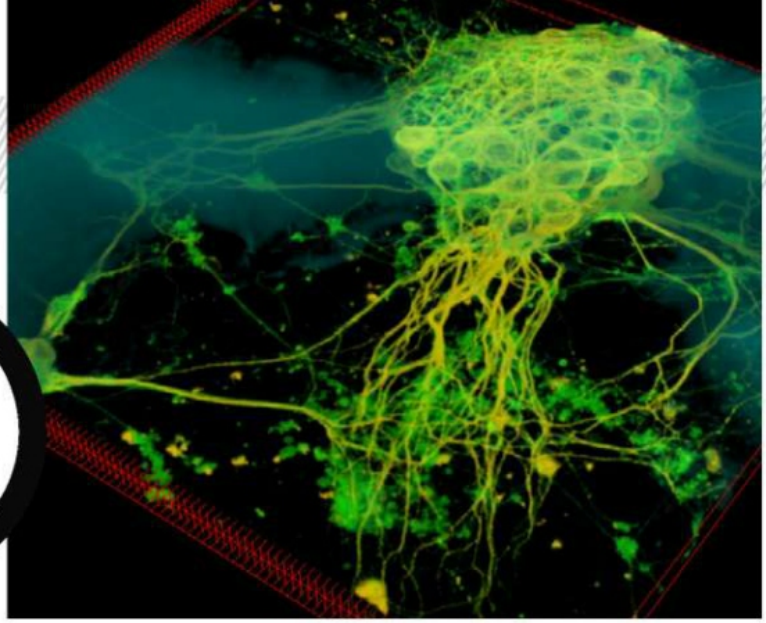
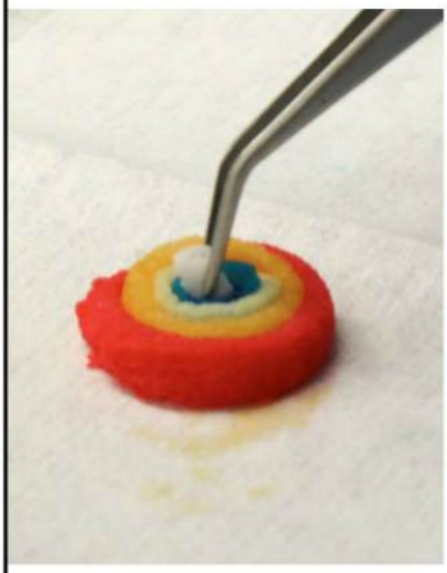


The Best Brain Model Yet

One little doughnut — a lab-engineered protein doughnut — could help researchers cure Alzheimer's and Parkinson's and restore a traumatized brain. In August, scientists at Tufts University unveiled a new 3-D human brain "doughnut" model that accurately imitates brain function and injury response.

David Kaplan and his team built their model by constructing a collagen gel-filled protein ring that cultures rat neurons. Unlike older, simpler models, this one's compartmentalized architecture (indicated by the multicolored rings) simulates the regions of the brain, and the chemically neutral protein allows neurons to connect realistically.



These multicolored protein ring doughnuts (above) mimic brain regions. The doughnut sustains neurons (top) for months, longer than any other brain model.

After growing the model for two months — previous ones lasted a few weeks at best — the team dropped different weights on the system to simulate brain trauma, like a concussion. Amazingly, all measured responses mimicked a human brain, making it the most realistic, responsive 3-D human brain model to date. And its longevity will allow researchers to introduce diseased cells to the model to better understand how brain diseases play out over time.

Although it's impressive, the model has limitations. It absorbs oxygen and nutrients through cell membranes, not blood vessels, shortening its life span. Researchers want to integrate a humanlike vascular component to "feed" the model and extend its already superior life span. – KATIE BO WILLIAMS

23

Freezing Light in Its Tracks

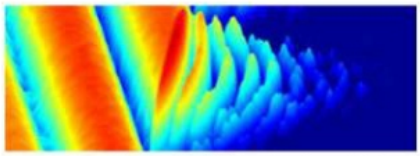
Light is thought to be the fastest stuff around, zipping so speedily through the universe that, even if it were tangible, you probably couldn't pin it down. But in September, physicists reported the seemingly impossible: They froze light into a crystal-like state.

Light particles, or photons, normally interact only with matter, not each other. But Princeton physicist Andrew Houck and colleagues built a device that effectively lets one photon trade energy with another, putting them in a crystal-like state. The device, about ¼ inch across, sounds simple: two tiny wires bridged at one end by a capacitor, with the other ends plugged into photon generators. The team first shot photons into the wires while blocking their exit with two-way mirrors, and the photons behaved normally, bouncing freely back and forth between the wires.

But when Houck's team added a tiny piece of supercooled aluminum near the ends not connected by the capacitor, they observed some odd effects. Because of the quirks of quantum physics (the unintuitive rules governing physical action, including that of particles, on the smallest of scales), the aluminum acted as a messenger between photons sent in the wires, imparting subtle changes on the photons with each bounce past it.

Eventually, the photons' energy levels changed so much that it took more energy to jump between wires than to stay put. When that happened, the photons froze in place on one of the wires, like water molecules losing heat until crystallizing into ice.

This frozen state — intangible and invisible to human eyes — is a brand-new behavior for light. And Houck is planning a bigger device with 200 wires. Such a system may help scientists understand matter's behavior when it gains or loses mass or energy. In other words, freezing photons could help shed light on the material world. – NEIL SAVAGE



Researchers "froze" light by allowing photons to interact with each other and lose energy, like water molecules losing heat and freezing.

COUNTERCLOCKWISE FROM TOP: DAVID KAPLAN/TUFTS UNIVERSITY (2); COURTESY JAMES RAFTERY AND ANDREW HOUCK/PRINCETON UNIVERSITY

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Chemical Spill Exposes Federal Loophole

Clockwise from top: Crude MCHM contaminated the Elk River in Charleston, W.Va., in January, after a storage tank ruptured at Freedom Industries. Many rallied at the state Capitol to demand safety measures, while area residents had to rely on bottled water for weeks.

Before 10,000 gallons of an obscure coal-processing chemical spilled into the Elk River near Charleston, W.Va., in January and contaminated water supplies for more than 300,000 residents, few people knew crude MCHM existed. The chemical isn't listed in the EPA's public database of toxic chemicals, and it's not federally regulated. Suddenly, the licorice-pungent compound was in the spotlight as the star of one of the worst water contamination episodes in U.S. history. But whether new safety measures for crude MCHM — and thousands of other unregulated industrial chemicals — will now take center stage remains unclear.

Crude MCHM, or 4-methylcyclohexane methanol, is used to purge impurities so coal burns more cleanly. But the cleaner itself is not so clean. As the compound flowed from a ruptured storage tank and its cracked containment pond at Freedom Industries' Etowah River Terminal — just 1.5 miles upstream from a drinking-water intake — hundreds of Charleston residents crowded hospital emergency rooms reporting nausea and other ailments.

At first, the Centers for Disease Control and Prevention said the contaminant posed little risk to public health, because concentrations of crude MCHM were measured at less than 1 part per million. But six days later, officials changed course, warning that pregnant women, children and other vulnerable residents should keep the taps turned off.

The confusion exposed a long-standing blind spot in U.S. environmental policy: Thousands of industrial chemicals lack sufficient health and safety information. That's because of a loophole in the 1976 Toxic Substances Control Act, which exempted chemicals already in use when Congress passed the law. At the time, officials presumed they were safe.

"This particular chemical is an example of tens of thousands of chemicals that are widely in commerce, but for which we know very little about their toxicology," says epidemiologist Lynn Goldman, who headed the EPA's toxic chemicals division in the 1990s and is now dean of public health at George Washington University.

As the chemical snaked through Charleston's water pipes, the CDC tracked down a single MCHM study, conducted by Eastman Kodak in 1990 to assess the risk to workers.

But the study, performed on rats, only examined short-term risks such as skin or eye irritation, Goldman notes. It wasn't designed to consider effects on public health.

A federal bill to close TSCA's loophole hasn't gotten very far. But a state measure to strengthen storage tank rules passed the West Virginia Legislature in the spring.

While the cleanup continues, public concern lingers. Four months after the spill, about two-thirds of residents said they still weren't drinking from the tap, according to a local health department survey. — APRIL REESE

FROM TOP: TYLER EVERT/ASSOCIATED PRESS/CORBIS (2); JAMES FASSINGER/CORBIS; JOHN RABY/ASSOCIATED PRESS/CORBIS

25

Diamonds Reveal Hidden 'Oceans' in Earth's Mantle

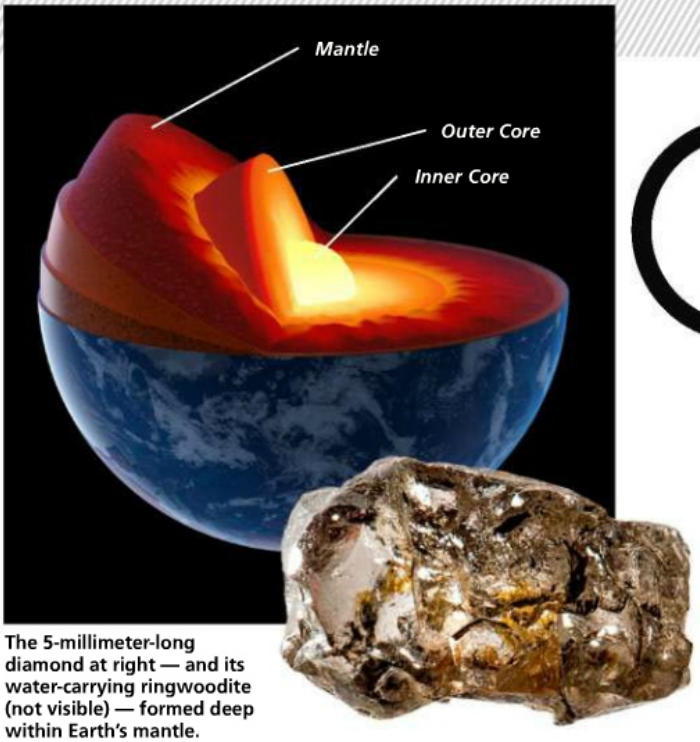
A tiny diamond weighing less than 1/200th of an ounce makes for a puny engagement ring, but what it tells geologists is priceless: Vast quantities of water might lurk unseen deep within the hot, thousand-degree confines of Earth.

In 2009, Canadian geochemist Graham Pearson and his graduate student John McNeill were analyzing a pile of diamonds that formed at least 325 miles underground hundreds of millions of years ago. After emerging through a volcanic explosion, the diamonds were found in 2008 at the edge of the Amazon rainforest. McNeill and Pearson were studying them to look for clues about the evolution and origin of the mantle, the thickest of Earth's inner layers.

After shining a laser into hundreds of diamonds, probing their composition, McNeill spotted something he hadn't seen before: a speck of a mineral called ringwoodite. Though thought to be plentiful in the planet's deep, high-pressure interior, scientists had previously seen the mineral only in meteorites, or synthesized in labs.

Within that speck of ringwoodite, it turned out, was something stranger: a tiny bit of water, trapped and distributed microscopically in the mineral during its formation. Pearson completed a detailed analysis of the diamond this year, confirming the water's discovery.

Finding direct evidence of a watery underworld "was a huge piece of luck," says Pearson. And that world could be very watery. The mantle is vast, and each speck of ringwoodite within it could contain water — potentially enough to rival the water in Earth's oceans. — SHANNON PALUS



The 5-millimeter-long diamond at right — and its water-carrying ringwoodite (not visible) — formed deep within Earth's mantle.

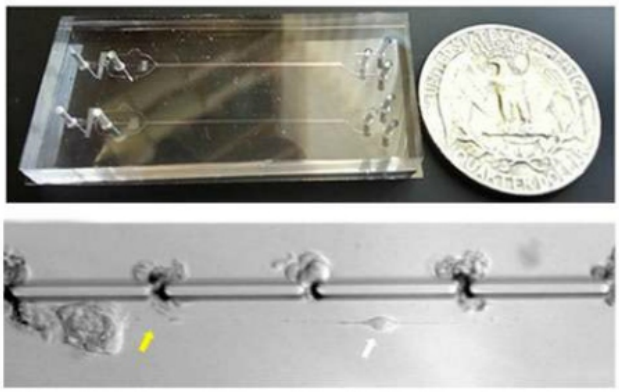
26

Platelet Production, Pumped Up

More than 2 million units of platelets — the blood cells responsible for clotting — are transfused each year, with cancer patients receiving an important share of them. However, donors alone can't possibly meet the need; platelets have a shelf life of only five days, and by 2019, demand will exceed supply by 533,000 units.

To ensure a steady, contaminant-free and abundant supply, in July Jonathan Thon's team at Brigham and Women's Hospital in Boston reported devising a bench-top "bioreactor on a chip." About the thickness of a quarter, the bioreactor "reproduces the physiology of bone marrow," says Thon.

When cells called megakaryocytes — derived from human stem cells — are pumped into the device and subjected to forces mimicking blood flow, they respond by making platelets. Next, Thon hopes to scale up the bioreactor to produce enough platelets for human trials. "It's not enough to make a lot of platelets," he says. "They need to be safe to go into people." — JEFF WHEELWRIGHT



A team at Brigham and Women's Hospital developed a small bioreactor (top) that can make fully functional human platelets. Artificially induced stress forces cells called megakaryocytes through tiny gaps (above) in the bioreactor's central channel. The cells squeeze through the gaps (yellow arrow) and break free (white arrow), forming platelets.

FROM TOP: JOHAN SWANEPOEL/SHUTTERSTOCK; RICHARD SIEMENS/UNIVERSITY OF ALBERTA; JONATHAN THON; BLOOD: JOURNAL OF THE AMERICAN SOCIETY OF HEMATOLOGY, JULY 21, 2014

27

New Chronology for Old Mummies

Funerary wrappings (above, right) from a 1920s excavation (left) suggest mummification is older than scientists thought. Analysis of the wrappings pushes the practice's timeline back nearly 1,000 years.

After sitting unnoticed for nearly a century, a handful of artifacts is rewriting ancient Egyptian history.

Egyptologists previously dated mummification's beginnings to the Old Kingdom period, about 2500 B.C. However, after conducting the first successful chemical analysis of linen used in Neolithic burials, researchers announced in August they had discovered that people living in what is now Egypt were mummifying their dead much earlier — as far back as 4300 B.C., more than a millennium before the establishment of the Egyptian state.

It can be difficult to find material that is reliably documented from pre-Dynastic Egypt, but textile expert Jana Jones of Australia's Macquarie University managed to identify the perfect specimen at the Bolton Museum, north of Manchester, England: fragmentary funerary wrappings more than 6,000 years old, collected in the early 20th century from a region of Upper Egypt.

After isolating material coating the textile fragments, University of York archaeological chemist Stephen Buckley analyzed its chemical makeup. He confirmed the substance was a man-made preservative and that it was virtually the same as compounds used at the height of the era of pharaohs.

"The surprise was that the recipe was so similar — both the constituents and the relative proportions — to what was used 3,000 years later," Buckley says.

Another surprise: Chemical signatures of some of the ingredients revealed they came from as far away as Turkey. The find suggests that Neolithic Egypt, generally seen as a disorganized society, was far more advanced and engaged in long-distance trade.

"It changes our understanding of the entire culture," Buckley says. "It shows they had an understanding of empirical science. Culturally, they were fairly sophisticated, and they were going to huge efforts to get these materials from the northeast Mediterranean to stick on a dead body." – GEMMA TARLACH

CLOCKWISE FROM LEFT: G. BRUNTON, MOSTAGEDDA AND THE TASIAN CULTURE (LONDON 1937) PL. VI; RON OLDFIELD AND JANA JONES (2)

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