SN
SCIENCE NEWS MAGAZINE
SOCIETY FOR SCIENCE & THE PUBLIC
OCTOBER 31, 2015

Bronze Age British Mummies

The Secret Life of Lungs

Teen Brains in Flux

Tricky Math Problem Solved

Nano Bites

Scientists investigate safety of tiny particles in food

Mermaid Reunites Long Lost Lovers

The perils of the sea are no match for the mermaid's treasure known as aquamarine.

Ever since ancient times, sailors have sworn by aquamarine as a talisman and protector for anyone traveling on the open water. According to legend, aquamarine originated in the treasure chest of mermaids, and has since ancient times, been regarded as "the sailor's lucky stone."

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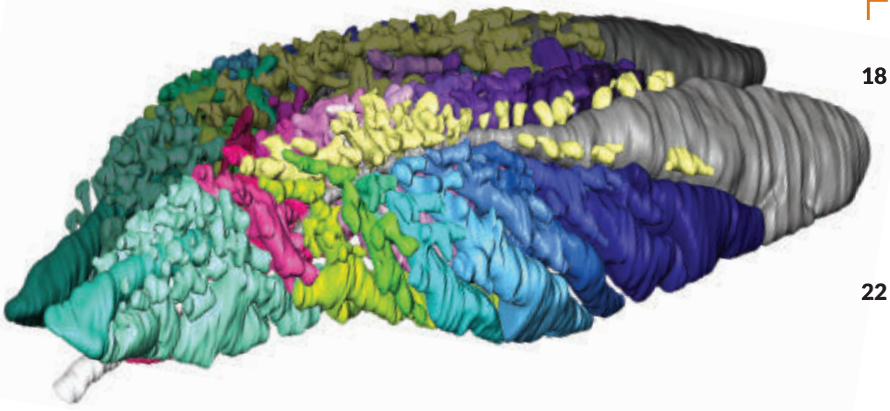
ScienceNews



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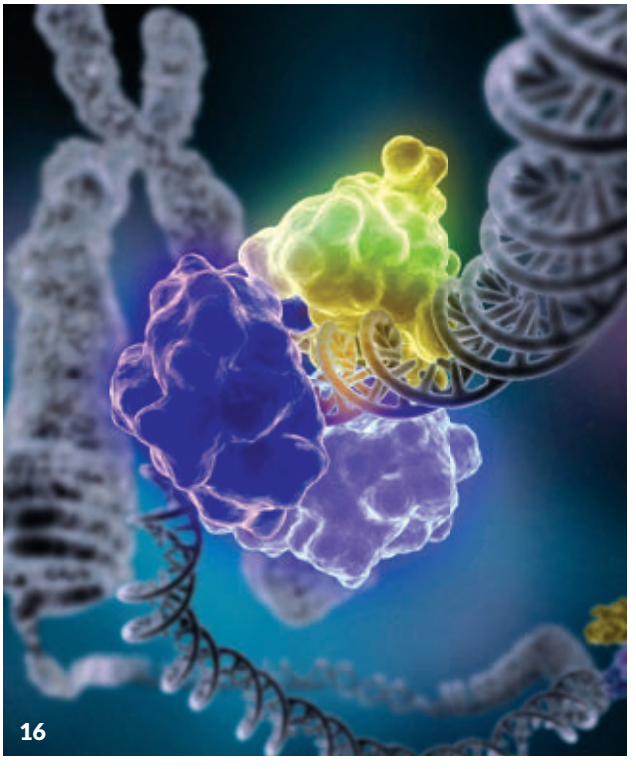

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Departments

COVER Powdered doughnuts are one of many packaged foods with nanoparticles, which may or may not be listed on the label. *Max Hirshfeld*

CLOCKWISE FROM TOP: E.R. SCHACHNER *ET AL*/*NATURE* 2013; MAURICIO DE PAIVA; COURTESY OF TOM ELLENBERGER/WASHINGTON UNIV. SCHOOL OF MEDICINE, VIA NIGMS

Perspiration is important, but inspiration is fun(damental)

How much of science is inspiration versus perspiration? Obviously, that creative spark, that new insight, that aha! moment is often crucial to producing new ideas and advancing knowledge. But, as both feature stories in this issue demonstrate, the real work comes after.

Biologist Colleen Farmer had her aha! in the form of a question about how alligators breathe — with an in-out stream like humans (as long believed) or a one-way flow like birds. As Susan Milius describes on Page 22, Farmer has spent years testing her idea, eventually showing that alligators and at least a few species of reptiles do have a one-way flow. Her work also raises bigger questions about lung evolution. If the often-languorous reptiles evolved the same breathing strategy as zippy birds, perhaps biologists need to rethink their interpretation of one-way flow as key to birds' energy-demanding lifestyle.

A candy's lingering sweet dust sparked environmental engineer Paul Westerhoff's new line of investigation, Susan Gaidos writes on Page 18. Seeing his son's face sprinkled white from a jawbreaker led him to take a closer look at what candy-makers put in their products. A trip to the grocery store followed by extensive lab analysis and high-tech microscopy ensued. He found that nano-sized food additives show up in a surprising variety of processed foods. Since nano-sized versions of traditional food additives do not have to be labeled, it's unclear (without doing your own experiments) which products contain them and in what quantities. Studies of how nanoparticles behave in the body, and whether they adversely affect health, are still ongoing. Many scientists are putting in long hours to answer the relevant questions.

Science, like genius, may be 99 percent perspiration, and it's valuable to recognize that. But game-changing flashes of insight give thrills, not just to scientists but also to the rest of us — and are fun to read about. So don't sweat it, dear readers, and enjoy learning about lungs and nanoparticles, as well as cometary crop circles (Page 5), the nonstop grazing of humans (Page 10) and the Nobel Prizes' recognition of science's best ideas/efforts (Page 16). — *Eva Emerson, Editor in Chief*

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SANDY SCHAFFER

Doctor ***Designed.*** Audiologist ***Tested.*** FDA ***Registered.***

Affordable *New* Digital Hearing Aid *Outperforms* Expensive Competitors Delivers *Crystal - Clear* Natural Sound

Reported by J. Page

Chicago: Board-certified Ear, Nose, and Throat physician Dr. S. Cherukuri has done it once again with his newest invention of a medical-grade, ALL-DIGITAL, affordable hearing aid.

This new digital hearing aid is packed with all the features of $3,000 competitors at a mere fraction of the cost. Now, most people with hearing loss are able to enjoy crystal clear natural sound — in a crowd, on the phone, in the wind — without suffering through "whistling" and annoying background noise.

After years of extensive research, Dr. Cherukuri has created a ***state-of-the-art*** digital hearing aid that's packed with the features of those expensive $3,000 competitors – at a ***fraction of the price***.

Digital Hearing Aid Outperforms Expensive Competitors

This sleek, lightweight, fully programmed hearing aid is the outgrowth of the digital revolution that is changing our world. While demand for "all things digital" caused most prices to plunge (consider DVD players and computers, which originally sold for thousands of dollars and today can be purchased at a fraction of that price), yet the cost of a digital medical hearing aid remains out of reach.

Dr. Cherukuri knew that many of his patients would benefit but couldn't afford the expense of these new digital hearing aids. Generally they are not covered by Medicare and most private health insurance policies.

The doctor evaluated all the high priced digital hearing aids on the market, broke them down to their base components, and then created his own affordable version — called the MDHearingAid ***AIR*** for its virtually invisible, lightweight appearance.

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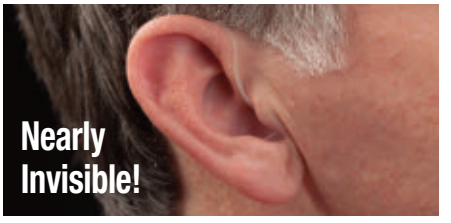
Of course, hearing is believing and we invite you to try it for yourself with our RISK-FREE 45-Day home trial. If you are not completely satisfied, simply return it within that time period for a full refund of your purchase price.

MDHearingAid® AIR



Ecstatic Users Cheer

"It is very comfortable, light and almost invisible. I can't stop raving about it." — Laraine T.

"I'm a physician, and this product is just as effective as (if not more than) traditional overly-priced hearing aids. I will be recommending (it)."— Dr. Chang

"As a retired advanced practice nurse, I purchased the MDHearingAid AIR after the Wall Street Journal *review. I am so pleased with the quality. You are providing a real service to our affordable health care."*— Ned R.

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Excerpt from the October 30, 1965, issue of *Science News Letter*

50 YEARS AGO

Ancient algae found

Tiny fossils of some of the oldest blue-green and green plants on Earth were found in well-preserved condition in Bitter Springs limestone in central Australia. The age of these prehistoric plants cannot be stated with certainty, but they probably are 700 million to 900 million years old.

UPDATE: The 1965 finding was one of the first fossil discoveries of early oxygen-producing photosynthetic organisms. Cyanobacteria — once known as blue-green algae and considered plants — were the first life-forms to produce oxygen. Today's oldest known cyanobacteria fossils date to around 2.1 billion years ago. But cyanobacteria debuted much earlier. During the Great Oxygenation Event, around 2.3 billion years ago, these microbes poured oxygen into Earth's atmosphere. And recently, researchers have reported evidence that oxygen-producing organisms existed long before that, perhaps 3.2 billion years ago (*SN Online: 9/8/15*).

The enigmatic tongue of the orange nectar-feeding bat picks up nectar without lapping or sipping.

IT'S ALIVE

How to drink like a bat

Sorry, English language, but "tongue pump" or even "conveyor belt" may turn into a verb for drinking.

Some very patient biologists have observed tropical bats drinking nectar in a way never documented before. Finding a term for this feeding is a challenge.

"Odd" is what Mirjam Knörnschild called it when she saw an orange nectar-feeding bat (*Lonchophylla robusta*) extend its tongue to drink. The bat didn't lick, lap, sip, slurp or even take its tongue out of the liquid. Along a deep groove on each side, edges undulated as if the tongue clenched in waves like the human intestine. Nectar just slid up the grooves. "It was like a conveyor belt," says Knörnschild, now of Free University of Berlin.

Hovering in front of a flower isn't cheap energywise, so an orange nectar-feeding bat must drink strategically, fast and often.

Efficient tongues matter in the strenuous life of a nectar specialist. A 15-gram bat like the orange nectar-feeder needs to drink about 1.5 times its body weight each night, requiring roughly 800 to 1,000 flower visits. At any given flower, "two seconds would be a long visit," Knörnschild says.

Under such pressure, extreme tongues have evolved, and not just in the orange nectar-feeding bat. Some flower-bat tongues end in patches of hairlike protrusions that engorge with blood and extend outward into a nectar mop. And a bat in South America stretches out a tongue 1.5 times the length of the rest of its body, Knörnschild says. This whopper tongue doesn't attach at the back of the mouth like typical mammal tongues but reaches down the throat to anchor between the sternum and the heart.

Orange nectar-feeders' tongues aren't as long but have great grooves. To see what free-flying bats do, colleagues Marco Tschapka and Tania Gonzalez-Terrazas of the University of Ulm spent long nights in Panama luring bats to hover in just the right position and babying a fussy high-speed camera not at all designed for jungles. "It sounds trivial, but it wasn't," Knörnschild says.

The bats drink with the tongue-in-place pumplike throbbing, the researchers report September 25 in *Science Advances*. The motion probably combines with the liquid-to-liquid attraction that also makes fluid rise in thin capillary tubes, the researchers suggest.

However it works, it's probably more exciting than the drinking mechanics of more famous specialists. Vampire bats don't actually suck blood, Knörnschild says: "They lick it like a cat would lap up milk." — *Susan Milius*

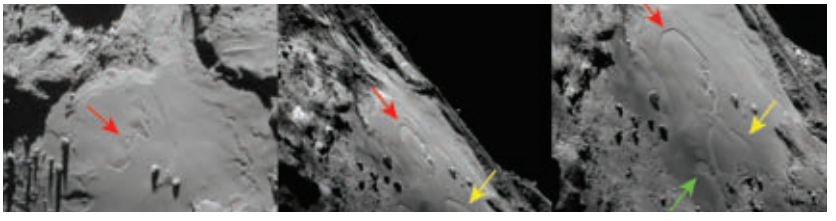
FROM TOP: M. TSCHAPKA/UNIV. OF ULM; HANS HILLEWAERT/WIKIMEDIA COMMONS (CC BY-SA 4.0)

Watch a bat drink while hovering over a tube of nectar at **bit.ly/SN_batdrink**

HOW BIZARRE

Mysterious dimples on a comet

A comet is growing its own version of crop circles. Five expanding disklike depressions appeared on 67P/Churyumov-Gerasimenko in images taken by the Rosetta spacecraft, which has been orbiting 67P since August 2014 (*SN: 9/6/14, p. 8*). The first roundish feature showed up on June 3 and was joined by a second 10 days later. Within a month, the first spot had grown to 220 meters across and 5 meters deep, and it had run into its neighbor. Three more spots appeared in early July, flanking the original two, researchers report September 15 in *Astronomy & Astrophysics*. The spots form around weak points in the surface, where sunlight can easily turn buried ice to vapor. That vapor in turn erodes the surrounding smooth plain — though the pits are growing too fast for sublimation alone to be their cause. Loosely bound dust or heat released by ice as it crystallizes might help the spots along. Unlike with crop circles, bored pranksters are probably off the hook. — *Christopher Crockett*



The first of five growing circles on comet 67P appears in a June 5 image from Rosetta (left). By June 23, two spots were spreading across the surface (center). They were joined by a third on July 2 (right).

INTRODUCING

New dinosaur identified in Alaska

Arctic dinosaurs have a new poster child. *Ugrunaaluk kuukpikensis*, a new species of duck-billed dinosaur, lived in what is now Alaska some 69 million years ago, scientists report September 22 in *Acta Palaeontologica Polonica*.

A geologist first discovered *Ugrunaaluk* fossils weathering out of a bluff in 1961. "It took 20 years before anyone actually realized the bones were from a dinosaur," says Patrick Druckenmiller, a paleontologist at the University of Alaska Fairbanks.

Scientists began expeditions to the bluff in the 1980s and have since discovered thousands of bones buried in mud and siltstone permafrost. But the skeletons had busted apart, and the bones came mostly from youngsters — so figuring out which species were represented was tricky.

Years spent cataloging and comparing bones convinced Druckenmiller's team that the Cretaceous Arctic had a new species (skeletal reconstruction shown), joining about a dozen other known dinosaurs from the region. The duck-billed dinos lived in polar forests, where yearly temperatures probably averaged around 4° Celsius, he says, roughly as cold as a refrigerator. Living conditions may have been tough: After round-the-clock daylight in the summer, winter would have plunged the dinosaurs into long stretches of darkness.

Adults may have reached 9 meters in length, about the length of two full-sized cars parked end to end. — *Meghan Rosen*

THE –EST

Oldest decapitated head in the Americas

A human skull found in a Brazilian rock-shelter represents the oldest known case of decapitation in the Americas, researchers report September 23 in *PLOS ONE*.

Radiocarbon dating places the skull at between 9,127 and 9,438 years old, says a team led by André Strauss of the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany. That's at least 4,000 years older than previous evidence of severed heads in South America and at least 1,000 years older than reported decapitation cases in North America. The skull might even be the oldest instance of decapitation in the world, but Strauss isn't sure.

Excavation of a small pit in the rock-shelter in July 2007 produced the skull. A pair of severed hands covered the skull's face. Incisions on one of six human neck bones in the pit denoted where the individual's head had been cut off.

Chemical analyses of a fossil tooth indicate that the decapitated person grew up eating local foods, as did 17 other ancient people interred in the rock-shelter. Head removal occurred after death as part of a ritual treatment of the body, Strauss suspects. — *Bruce Bower*

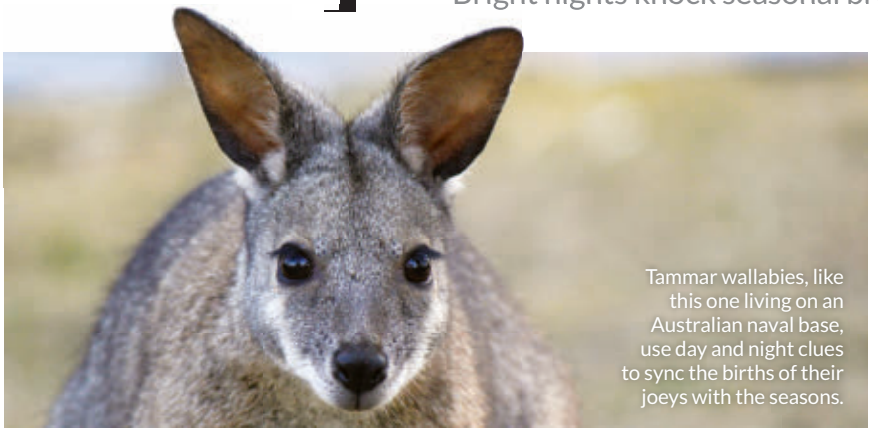
9,127–9,438
years old
Age of decapitated human skull shown above

FROM TOP: MAURICIO DE PAIVA; MPS FOR OSIRIS TEAM/ROSETTA/ESA, MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA; MICHAEL HOLLAND PRODUCTIONS, LAURIE SPICHER

LIFE & EVOLUTION

Artificial light tricks wild wallabies

Bright nights knock seasonal breeders out of sync with food



Tammar wallabies, like this one living on an Australian naval base, use day and night clues to sync the births of their joeys with the seasons.

BY SUSAN MILIUS

Artificial lighting at night delays wild tammar wallaby breeding, potentially pushing the nursing marsupial moms out of sync with their peak season for food.

Tammar wallabies (*Macropus eugenii*) that live on the well-lit landscape of Australia's largest naval base muddle the timing of their natural breeding season. Births peak in February — a month later on average than normal — then dip only to surge again in April, says zoologist Kylie Robert of La Trobe University in Melbourne, Australia. By the time these late-arriving joeys have grown in the pouch to their most demanding stage some 250 days later, the best grazing greened by winter rains is fading. Nursing moms and their joeys once got through this season thanks to all the irrigated lawns on the base. New irrigation rules, however, leave the wallabies facing food shortages.

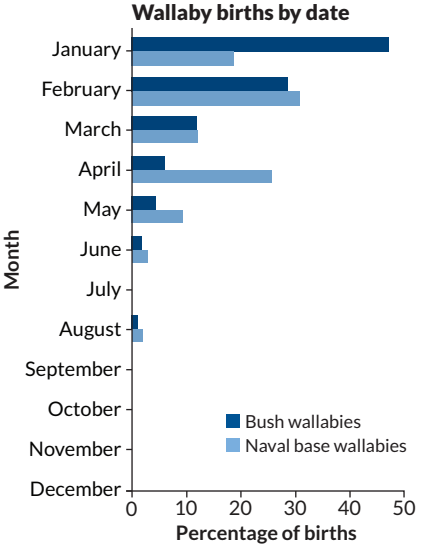
In contrast, about six kilometers away where it's still dark at night, wallaby births peak in January. Blood chemistry analyses show that wallabies in the unlit wilds respond to darkness cues more than their naval neighbors do, Robert and colleagues report in the Oct. 7 *Proceedings of the Royal Society B*.

"We have reams and reams and reams of lab data about the effects of light on reproduction," says urban ecologist Travis Longcore of the University of Southern California in Los Angeles. "The important thing here is [that the researchers are] showing that it's happening in the wild with the animals going about their normal behavior."

Studies in birds have shown that exposure to artificial light can push forward reproductive timing in the wild, Robert notes.

Light pollution seemed a plausible explanation for the wallabies, too. For other reasons, Robert and colleagues were trapping the marsupials on Garden Island, where the naval base is, and noticed the lag in birthdates.

Lights on, lights off Tammar wallabies in the bush tend to give birth in January. At a nearby lit-up naval base, births peak later, leaving nursing moms vulnerable to food shortages.



The team used light data from sensors on 14 tammar wallabies, seven hopping around the bush and seven on the naval base. The five in the bush experienced some night light around the time of full moons but not much otherwise. The naval base "was lit up like a Christmas tree, as you can imagine, for security reasons," Robert says. There, the sensors indicated wallabies experience 10 times as much light intensity at night as bush animals.

That difference also showed up in blood levels of melatonin, a hormone that builds up in darkness and helps the animals pick up seasonal cues and regulate body rhythms. In 67 wallabies tested, nighttime melatonin levels in bush animals were more than twice as high on average compared with melatonin levels in the naval base wallabies.

That difference fits with what biologists have learned about reproduction in tammar wallabies. When a tammar wallaby mates early in the year, the fertilized egg stops dividing for months. When nights start lengthening after the Australian summer solstice (around December 22), the increase in darkness boosts melatonin, and the embryo starts developing again. The wallaby then gives birth to a peanut-sized joey in the early months of the year. While still nursing, the mom mates again within 24 hours. This newly fertilized egg soon suspends cell division — until the waning days after the next summer solstice kick up melatonin again. The melatonin helps the animals reproduce in sync with the seasons.

John Swaddle, an evolutionary ecologist at the College of William & Mary in Williamsburg, Va., would like to know what would happen if some naval wallabies swapped places with bush ones. Robert hasn't tried that, but she says that tammar wallabies sent to North American zoos changed their reproductive timing by as much as six months to fit their new continent's day lengths. ■

FROM TOP: K.A. ROBERT; K.A. ROBERT *ET AL./PROCEEDINGS OF THE ROYAL SOCIETY B* 2015

MATH & TECHNOLOGY

83-year-old math problem solved

Proposal by Erdős involving number sequences validated

BY ANDREW GRANT

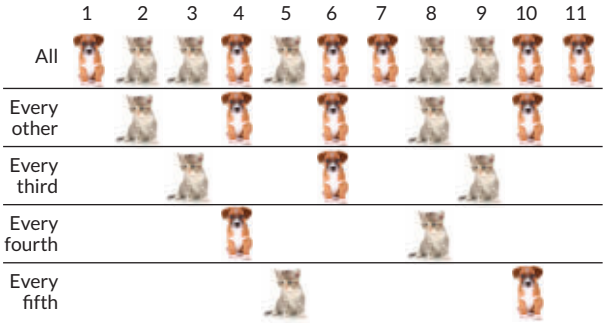
It took more than 80 years, but a problem posed by a mathematician who delighted in concocting tricky challenges has finally been solved.

UCLA mathematician Terence Tao has produced a solution to the Erdős discrepancy problem, named after the enigmatic Hungarian numbers wizard Paul Erdős. Tao's proof, posted online September 17 at arXiv.org, shows that the difference (or discrepancy) between the quantities of two elements within certain sequences can grow without bound, even if someone does the best possible job of minimizing the discrepancy.

"Based on Tao's stature, I would trust it straightaway," even though the proof hasn't yet been peer-reviewed, says Alexei Lisitsa, a computer scientist at the University of Liverpool in England.

While the problem probably doesn't have real-world applications, Tao says, "the act of solving a problem like this often gives a trick for solving more complicated things."

The Erdős discrepancy problem involves a sequence of numbers, 1s and –1s. To visualize, think of a line of puppies and kittens. The goal is to line them up so that as you go down the queue, the discrepancy between the number of dogs and cats stays as small as possible. It's easy at first: Just alternate the animals and the difference will never exceed one. The real challenge is to also minimize the discrepancy when considering only every other animal (the second, fourth, sixth and so on). Then do the same for similar subsets of the line: every third, every fourth and so on.



Furry math The Erdős discrepancy problem examines sequences of 1s and –1s or, in this case, puppies and kittens. The goal is to see how effectively one can minimize the difference between the number of cats and dogs in various subsequences. Here, the difference in each row doesn't exceed one.

In 1932, Erdős proposed that with enough numbers in a sequence, there is no limit to how high the discrepancy can get. But Erdős, who died in 1996, left it up to his fellow mathematicians to validate his hypothesis.

> "The act of solving a problem like this often gives a trick for solving more complicated things."
>
> TERENCE TAO

The problem didn't attract much attention until about five years ago, when Tao and collaborators made some progress (*SN Online: 12/8/09*). Tao says he all but forgot about the problem until this year, when he started working with mathematicians who had achieved a major insight into what are called multiplicative functions. Understanding those functions turned out to be essential for sorting through some thorny sequences that minimize discrepancies. (Tao didn't make the connection at first — a commenter on his blog did.) Tao devised a full solution proving that Erdős was right: The discrepancy can grow infinitely large.

Lisitsa says Tao's solution is even more impressive because of its brevity. Tao's paper is 20 pages. Lisitsa and a colleague recently designed a computer algorithm that required hundreds of megabytes' worth of text just to prove that a line of 1,161 1s and –1s always yields a discrepancy of at least three in one of the subsequences. "It's a kind of confirmation of human power over computers," Lisitsa says. ■

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GENES & CELLS

Protein buildup triggers cellular aging

GATA4 could be target for treating senescence-related diseases

BY SARAH SCHWARTZ

A biochemical switch can seal a cell's fate, scientists have discovered.

A buildup of the protein GATA4 forces cells to enter a permanently static state known as senescence, researchers report in the Sept. 25 *Science*. The discovery sheds light on a complex biological process linked to aging.

Senescence — in which cells stop growing and dividing — results from serious stress and genetic damage, says study coauthor Stephen Elledge of Harvard Medical School. GATA4 helps turn on this response. The researchers found that senescent cells had higher levels of GATA4 than normal cells and that producing the protein in human connective tissue cells turned the cells senescent.

In the study, the researchers found that GATA4 accumulated with age, building up to greater concentrations in the kidneys and livers of older mice and in the brain cells of older people.

In healthy, dividing cells, GATA4 is gobbled up and broken down. But this cleanup process slows in damaged cells, causing the protein to collect and initiate senescence, the researchers found.

Targeting GATA4 may create new therapies for age-related diseases that are linked to senescent cells such as Alzheimer's and atherosclerosis, says geriatrician James Kirkland of the Mayo Clinic in Rochester, Minn. "This opens the door to at least considering that, and doing additional experiments to test that." ■

BODY & BRAIN

Adolescent brains open to change

Teens' neural wiring is extra sensitive to outside influences

BY LAURA SANDERS

Under the carefully styled hair of a teenager, the brain is roiling with change. Some nerve cells are killed off, others are pruned back and still others are locked into place — a restyling that moves the brain closer to its adult form. This dramatic adolescent makeover represents a window of opportunity known as a sensitive period, allowing the brain to be selectively shaped by the outside world, new studies hint.

Such sensitive periods are common throughout the first years of life. Incoming sights, sounds and social interactions all pattern the young brain in a way that lets it detect and respond to its particular environment (*SN: 8/11/12, p. 18*). Within a few years, though, those windows of neural malleability close. But new research suggests that for certain kinds of input, the window may fly back open during adolescence.

Compared with the brains of children and adults, adolescent brains may be especially susceptible to certain kinds of information, such as memory training, social influences or drugs. Even a commonly used treatment to ease fear memories may have different effects during adolescence, scientists are finding.

This heightened malleability of the adolescent brain isn't the same as the sensitive periods in early childhood, says Jay Giedd, a psychiatrist at the University of California, San Diego. When it comes to the brain, adolescence is not a "second toddlerhood," he says. Instead, something different — and fascinating — is going on.

Adolescent brains may be especially susceptible to certain kinds of information.

Proving that the adolescent human brain really does show a peak of sensitivity to certain signals in the environment will be tough, though, says Delia Fuhrmann, a cognitive neuroscientist at University College London. To make the case, scientists must show that some inputs affect an adolescent's brain more than they affect children and adults, she and colleagues argue in the October *Trends in Cognitive Sciences*.

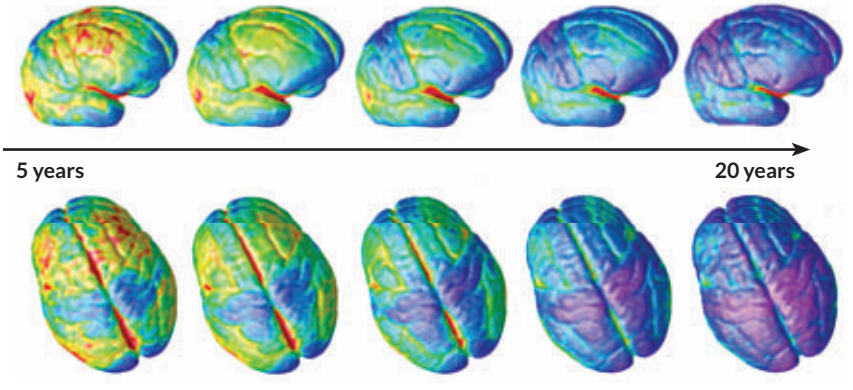
Such comparisons have already been made in some cases. In lab experiments, adolescents were more likely than both children and adults to hold on to fearful memories, neuroscientist BJ Casey of Weill Cornell Medicine in New York City and colleagues reported in 2012 in the *Proceedings of the National Academy of Sciences*. Adolescents learned to associate a colored square with a blast of noise. Later, after the noise was turned off, adolescents shown the square continued to react as if they were going to hear the blast, whereas children and adults learned that the colored square was safe again. Adolescent mice showed the same distinct behavior. The differences between age groups are "not by any means gradual," Casey says. "Adolescents show a completely different response than children and adults."

Those results suggest that adolescents are paying close attention to danger signals. "Teenagers remain incredibly sensitive to these cues," Casey says. And in most cases, "it's probably very good for them to be vigilant." That helps adolescents learn about and adapt to the world, she says.

That reluctance to let go of scary signals may have implications for therapies aimed at easing fearful memories in adolescents, Casey and colleagues argued in 2014 in *Biological Psychiatry*. Cognitive behavioral therapy can include exposure to a fear trigger multiple times, in an effort to help a person learn that the signal is now safe. But because adolescents may have a stronger hold on these memories, this approach might not work well for them.

Other aspects of memory also seem to be distinct during adolescence, Fuhrmann says. By some measures, working memory, or the ability to hold on to and mentally juggle multiple things simultaneously, peaks during adolescence, scientists have found. And people are more likely to remember events

Gray matter volume declines over time



J. GIEDD, ADAPTED BY M. TELFER

How the teen brain changes

1. **Gray matter** throughout the brain shrinks in adolescence (blue and purple indicate a lower volume of gray matter, as shown in the diagram above), a sign that the brain is becoming more specialized.
2. **Nerve cells** in parts of the outer layer of the brain, called the cortex, get wrapped with myelin, an insulating substance that helps speed signals.
3. **Communication links** between distant parts of the brain, called white matter tracts, start to solidify into an adultlike structure.

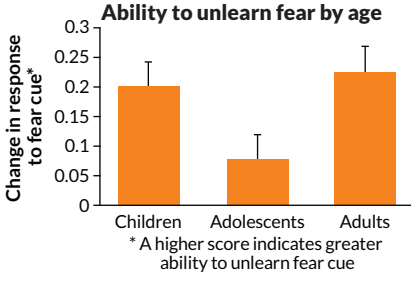
that happened between ages 10 and 30, suggesting that autobiographical memories are particularly strong during these years. But whether those skills stem from a greater receptivity to incoming information isn't clear, Fuhrmann says. To know that, scientists need to test whether adolescents' memories can be improved more with practice than those of both children and adults.

Adolescents may also be more vulnerable to the ill effects of drugs, animal studies suggest. Rats given cannabis during adolescence showed more cognitive problems than rats that received the drug during either early life or as adults, several studies have found. Similar results were seen with cocaine: When rats were allowed to take cocaine during adolescence, they became more likely to take more cocaine when stressed later in life, researchers reported July 23 in *Addiction Biology*.

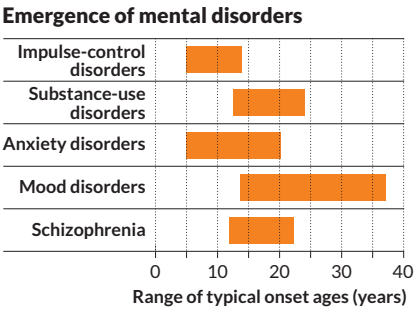
While those results are suggestive, they come from animals. It's not clear yet whether drugs have outsized consequences for human adolescents, who can be drawn to experiment with illegal substances as a way to explore their world.

But "exploration doesn't have to mean doing ecstasy all day," says Beatriz Luna, a developmental cognitive neuroscientist at the University of Pittsburgh. Adolescents are primed to seek out new experiences in an effort to accumulate knowledge about how to navigate their social world. "We think about it as a period of specialization," she says. "Up to that point, you've been building up brain structure and abilities, and now you're specializing to fit your particular environment. This is when brain processes become more committed."

Feeling fear Adolescents hold on more strongly to fear associations than children or adults. That difference has implications for treatments to ease fearful memories.
SOURCE: S.S. PATTWELL *ET AL*/*PNAS* 2012



M. TELFER



Teen onset Mental illnesses such as schizophrenia and mood disorders often appear during adolescence. SOURCE: T. PAUS, M. KESHAVAN AND J.N. GIEDD/*NATURE REVIEWS NEUROSCIENCE* 2008

On September 25, the National Institutes of Health announced a research project that will follow about 10,000 children in cities around the United States beginning at ages 9 or 10. Scientists will track drug use, mental illness, academic skills and other measures, and attempt to link those experiences with brain differences. Called the Adolescent Brain Cognitive Development Study, the project's goal is to clarify how the adolescent brain responds to certain kinds of input.

Finding out more has big implications for things like education, juvenile crime and mental illness. Many disorders such as schizophrenia, depression and anxiety can appear during adolescence, suggesting that the brain is particularly susceptible during this window.

"There's a lot we don't know," Casey says. Although scientists don't yet understand the specifics of how certain kinds of information change the adolescent brain, it is clear that the world has a big effect. "It's this beautiful interaction" between environment and neural development, Casey says. "It's brains getting wired." ■

LIFE & EVOLUTION

Math describes herd fluctuations

Equations quantify periodic spreading, clustering in sheep

BY SARAH SCHWARTZ

There's something in the way sheep move.

In a herd, merino sheep follow a predictable pattern of spreading out and clustering together. Now scientists have developed equations that describe those movements. The sheep's choreography may allow them to balance their needs for food and protection, researchers report September 28 in the *Proceedings of the National Academy of Sciences*.

"This is the first quantitative study of this kind of behavior," says study coauthor Francesco Ginelli of the University of Aberdeen in Scotland.

The results suggest that a herd exists in a delicate balance, close to a "tipping point" between dispersing and huddling, says statistical physicist Andrea Cavagna of the Institute for Complex Systems of the National Research Council in Rome.

An observed group of 100 ewes slowly drifted apart while grazing, only to suddenly clump back together roughly every 15 minutes, the researchers report. The behavior occurred unprompted, without any predator to spook the herd. Sheep toward the outside of the herd seemed to initiate each woolly avalanche by running toward the center of the group, tailed by their neighbors.

Ginelli thinks that a herd's oscillations balance two interests: maximizing grazing space and having safety in numbers should a predator approach. "The interpretation — balancing these two things — it's simple and elegant," Cavagna says. The team's mathematical model supports this proposed behavior, he says.

Ginelli plans to examine larger groups of sheep, and he may explore what happens if a single sheep gets spooked. The results may help scientists understand the behavior of other animals — for example, humans fleeing a burning building. ■

GENES & CELLS

Mobile app busts mealtime myth

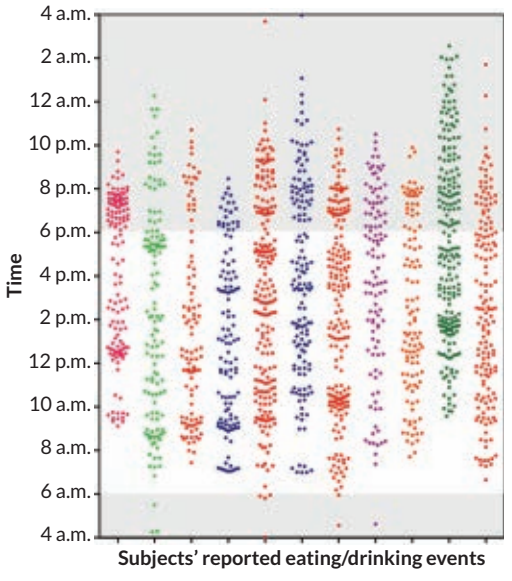
Restricting eating hours aids in weight loss, study shows

BY TINA HESMAN SAEY

Three meals a day is a myth. People eat all the time, a new study shows.

People eat almost constantly for about 15 hours a day, nearly all of their waking hours, researchers learned from studying smartphone pictures that volunteers took of their food and drinks. Restricting eating time to a 10-hour stretch per day led to weight loss in a small group of overweight study participants, researchers report online September 24 in *Cell Metabolism*. The findings are part of a growing body of evidence that timing of meals is important for health.

In previous studies, circadian biologist Satchidananda Panda of the Salk Institute for Biological Studies in La Jolla, Calif., and colleagues showed that restricting when mice or fruit flies were allowed to eat could influence weight gain and heart health (*SN: 4/4/15, p. 7*).



Time to eat Participants in a study to determine when people eat did not maintain regular mealtimes, instead stringing eating out over nearly 15 hours each day. Patterns for 11 participants are shown; dots represent an event when a person ate or drank something other than water.

Critics of the work have long contended that the animal studies don't apply to humans, because everybody knows that people eat three meals a day within a 12-hour period, Panda says. But he and lab colleague Shubhroz Gill, now at the Broad Institute of MIT and Harvard, weren't convinced.

They recruited 156 people living in the San Diego area to take pictures of everything that went in their mouths — including food, drinks and even vitamins — for three weeks. Unbeknownst to the participants, their pictures were time-stamped. Some participants also wore a wristband that tracked their activity and exposure to light.

> People eat almost constantly for about 15 hours a day, nearly all of their waking hours.

When analyzing the eating patterns, Panda and Gill couldn't pick out defined breakfast, lunch and dinner times for most participants. People started eating about 1½ hours after waking up and finished a couple of hours before bedtime with no discernible large breaks in between, the researchers found. About 25 percent of calories were eaten before noon, and 37.5 percent consumed after 6 p.m.

That pattern may contribute to weight gain, says Kenneth Wright, a physiologist at the University of Colorado Boulder. For instance, sleep-deprived people tend to eat more in the evening, and that eating pattern has been associated with gaining weight, he says.

On weekends, people started eating an hour or more later than they did on weekdays. That's the equivalent of changing time zones every weekend and may produce metabolic jet lag, Panda says.

Wright says the results may surprise some people, but shouldn't come as a shock. For many people in the United States, food is never far away, he says. "All we have to do is reach for the refrigerator or the vending machine or the [snack] drawer."

Eight participants who were overweight and strung their eating out over 14 hours or more each day were asked to cut eating time back to just 10 hours a day without otherwise changing their diets or lifestyle. Restricting eating time cut back calorie intake by an average of about 20 percent, the researchers found.

Over 16 weeks, the overweight participants lost an average of 3.27 kilograms (about 7.2 pounds). Participants also reported that they slept better, had more energy and were less hungry at night. All of them voluntarily continued to limit eating to 10 hours per day for a year. They maintained their weight loss and the sleep and energy benefits.

Many diet studies have demonstrated weight loss, but few people in those studies have kept the pounds at bay, Wright says. "It's a huge benefit to show you can do this in the real world and sustain it."

Diet research is usually concerned with calories or the type of food people eat, says Thomas Woolf, a physiologist at Johns Hopkins University. "This adds a temporal component."

It's not clear how much time people should spend eating each day, he says. "What's the optimal time window, and is it global or is it individual?" Woolf and colleagues at several institutions hope to launch a similar tracking study this fall to study 10,000 to 40,000 people at risk for developing diabetes. That investigation will use smartphone apps and activity monitors to help people track and perhaps change their eating and exercise habits for the better.

Participants in the study reported that changing when they ate was easier than changing what they ate, Panda says. That's encouraging for researchers who try to apply results from animal studies to humans, he says. "When it comes to translation, it's about whether people can do it or not as to whether they get the benefits." ■

S. GILL AND S. PANDA/*CELL METABOLISM* 2015

MATTER & ENERGY

Chemists finally create elusive acid

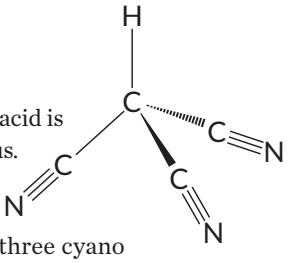
Textbook chemical cyanoform was sought for over a century

BY BETH MOLE

After more than a century of effort, chemists have nabbed a legendary acid.

Cyanoform, or tricyanomethane, appears widely in textbooks as one of the strongest carbon-based acids. Yet despite repeated attempts to make the acid, cyanoform has evaded chemists until now. Researchers report September 18 in *Angewandte Chemie International Edition* that they isolated the acid by figuring out crucial experimental conditions.

The main problem was temperature, says Andreas Kornath, an inorganic chemist at Ludwig Maximilian University of Munich. Chemists had assumed that cyanoform is stable at room temperature. But using trial and error, Kornath and his team found that the acid is stable only below –40° Celsius.



Try, try again At last, researchers have isolated cyanoform (chemical structure shown), a strong carbon acid, by making it at very cold temperatures.

Cyanoform has a central carbon atom attached to a hydrogen atom and to three cyano groups, each consisting of a carbon triple-bonded to a nitrogen. The molecule easily loses its hydrogen, making it a strong acid and demonstrating a rule of carbon acids — electron-loving groups (the cyano groups) attached to a central hydrogen-toting carbon pull on that carbon's electrons. The molecule's electrons settle into a position close to the cyano groups, weakening the link to the hydrogen.

At room temperature, cyanoform decomposes, forming junk molecules, Kornath says. That probably happened when chemist Hermann Schmidtmann tried to make cyanoform in 1896. He mixed sulfuric acid with a stable relative of cyanoform called sodium tricyanomethanide. That molecule, a salt of cyanoform, has the same structure as the acid except it has lost the positive hydrogen ion, resulting in a negative molecule that is paired with a positive sodium ion.

Schmidtmann expected that sulfuric acid would stick a hydrogen atom onto the negative tricyanomethanide, forming cyanoform. Instead, he ended up with a concoction that probably contained only remnants of the unstable acid.

But at frigid temperatures, Kornath and colleagues made the acid. The team reacted a strong acid, hydrogen fluoride, with a salt of cyanoform. Multiple chemical analyses showed that the resulting molecule matched cyanoform's structure.

"It's very noteworthy," says physical chemist Daniel Kuroda of Louisiana State University in Baton Rouge. Theoretical chemistry cannot predict the temperatures at which substances decompose, he says. But experimental information like this gives chemists new ideas. ■

MATTER & ENERGY

Time-reversal mirror sends light back

No matter the angle, waves are returned along the same path

BY ANDREW GRANT

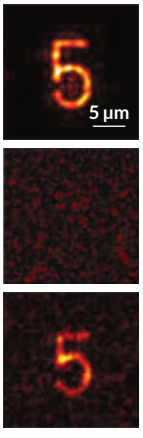
Light that strikes a new and improved mirror is always returned to sender.

South Korean physicists have created a composite mirror, made up of about 1,000 tiny reflectors, that coaxes light waves to retrace, in reverse, the paths taken by the original waves that struck it. As a result, the researchers could reproduce an image at the same spot where it originated, even though the initial light waves had been severely scattered on their way to the mirror.

This phase-conjugation mirror, reported in the Oct. 9 *Physical Review Letters*, is not the first of its kind, but it requires less equipment and preparation time than its predecessors. "It's very simple and elegant," says Allard Mosk, a physicist at the University of Twente in Enschede, the Netherlands.

The researchers tested the device by projecting an image of the numeral 5 through materials, including raw chicken, that scrambled the light. After a brief calibration, the mirror sent light waves that passed back through the chicken again and combined to re-create the "5."

A typical wall mirror manipulates light by reflection, often sending waves bounding off in a new direction. Waves coming in at an angle from the left, for instance, rebound toward the right. But light that hits the mirror head-on bounces back to where it originated. In this case, the mirror exhibits time-reversal symmetry: A video of the reflected wave would look identical to a video of the incoming wave played in reverse.



Light from an image of the numeral 5 (top) was scrambled (middle) after passing through raw chicken. A time-reversal mirror then reproduced the same image (bottom).

A phase-conjugation mirror, also called a time-reversal mirror, performs this return-to-sender process regardless of the angle at which light strikes. The mirror works by reversing the direction of motion of each light wave while preserving the wave's original shape. That's easier said than done, Mosk says. Previous time-reversal mirror prototypes required complicated optical tricks such as firing multiple lasers to reconstruct the desired wave shape.

YongKeun Park, a biomedical optics physicist at the Korea Advanced Institute of Science and Technology in Daejeon, and colleagues came up with a simpler solution. When the chicken-scattered light from the "5" reached the team's mirror, a computer automatically shifted the mirror's reflectors until they focused the light into a narrow beam, signaling that the mirror was calibrated. The researchers then fired laser light that bounced off the mirror and passed through the chicken. It was like hitting a rewind

EARTH & ENVIRONMENT

Double blow may have killed off dinos

Timing of Cretaceous impact coincides with surge in lava flows

BY SARAH SCHWARTZ

The demise of the dinosaurs may have been the result of a coordinated one-two punch.

Volcanic eruptions in what is now India appear to have increased around the time of the asteroid impact that preceded the Cretaceous extinction that killed off the dinosaurs, scientists report in the Oct. 2 *Science*. The close timing between the two events suggests that the impact could have triggered this volcanic shift, the researchers say.

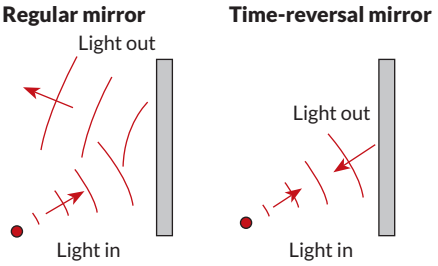
Scientists have debated whether eruptions assisted the Chicxulub asteroid impact in wiping out over half of the planet's species at the end of the Cretaceous period, roughly 66 million years ago. Previous studies have shown that while the eruptions in western India's Deccan Traps began a few million years before the extinction event, volcanic activity surged closer to the time of the asteroid collision. In the new study, researchers report that during this volcanic shift, the amount of lava flooding the Deccan Traps roughly doubled, despite fewer overall eruptions. Scientists previously estimated that the impact and the lava surge were separated by less than 100,000 years; the new study places the two events within about 50,000 years of each other.

"They both happened at effectively the same time, which is why we think there's a causal link between them," says study coauthor Paul Renne, a geochronologist at the Berkeley Geochronology Center in California. Earthquakes can be linked to small volcanic eruptions, so the Chicxulub impact — which would have caused the equivalent of a magnitude 10 quake or greater — could have shifted Deccan volcanism, Renne says.

The new analysis combined previous data with new samples taken from layers of rock in the Deccan Traps. The researchers estimated the ages of samples by measuring the ratio of two forms of argon gas, a number that represents the amount of radioactive decay of potassium to argon in a sample over time. Renne hopes further research will narrow down the window of when the shift in eruptions occurred, perhaps even to 5,000 years. "These results are really suggestive," he says. "We'd like them to be conclusive."

Geochronologist Blair Schoene of Princeton University points out that the study includes samples from only before and after the extinction event, but none

K. LEE *ET AL*/*PHYSICAL REVIEW LETTERS* 2015



Bounce back A typical mirror reflects light in a new direction. But a time-reversal mirror always sends light straight back from where it came.

button. Because the laser light reentered the chicken exactly where the scattered light had emerged earlier, and along the same trajectories and angles, the poultry passage unscrambled the light. The "5" reappeared at its original location.

Phase-conjugation mirrors' ability to focus and unscramble light may have medical applications. Mosk envisions doctors injecting a dye or other agent to make cancer cells glow inside the body. A mirror would gather up that light, even after it's been scattered by other tissues, and send back a high-energy beam that strikes and sears only the cancer cells. ■

during the die-off itself. To clarify the cause and process of the mass extinction, that gap needs to be filled. The new research, he says, "is certainly a great step in that direction, but there's more work to be done."

Understanding the process behind the extinction may prove challenging. Data show a clear link between the asteroid impact and extinction patterns worldwide, but scientists haven't found signs of a global effect of the volcanism at the end of the Cretaceous period, says paleontologist David Fastovsky of the University of Rhode Island in Kingston.

And ultimately, it's impossible to determine if volcanic activity or the asteroid impact caused the extinction, he says. "The pattern that would be left from the volcanism is in fact indistinguishable from the pattern that's left from the asteroid," Fastovsky says. "It's fundamentally untestable." ■

K. LEE ET AL/PHYSICAL REVIEW LETTERS 2015

BODY & BRAIN

DNA varies from neuron to neuron

Neighboring nerve cells can have distinct genetic makeups

BY LAURA SANDERS

Nerve cells in the brain don't all work from the same genetic blueprint. Individual neurons within a person's skull harbor over 1,000 distinct DNA mutations, scientists report in the Oct. 2 *Science*.

The study "shows something fascinating — every neuron probably has a unique genome," says neuroscientist Mike McConnell of the University of Virginia in Charlottesville. That variation may have important implications for how the brain grows and functions normally, and for when problems arise.

"We're no longer saying, 'Do neurons have different genomes?' " McConnell says. "We're saying, 'Let's figure out how that matters.' "

Molecular biologist Michael Lodato and neuroscientist Mollie Woodworth of Boston Children's Hospital and Harvard Medical School and colleagues scrutinized 36 neurons taken from postmortem brains of three people. The researchers figured out the arrangement of the four molecular building blocks, called bases or nucleotides, that make up the cells' DNA. Mutations were identified by looking for unexpected bases popping up in the sequence.

> "This idea that every cell in the body has the same genome is not true."
>
> MOLLIE WOODWORTH

Earlier studies had found individual neurons with changes in large chunks of DNA, but no one had carefully tallied up single base changes, called single nucleotide variants. "We didn't know what the breadth and the characteristics and the dynamics of these mutations were in single cells," Lodato says.

It turns out that the neurons were riddled with mutations — each cell had about 1,500 DNA changes, most of which were unique to that cell. "We were pretty surprised about the number we found," Lodato says. The finding suggests that two neighboring neurons are probably operating from different genetic blueprints, he says.

That variety may have implications for how the brain — and the rest of the body — works, Woodworth says. "This idea that every cell in the body has the same genome is not true."

Cancer cells and other cells in the body can rack up mutations as they divide. But most neurons in the brain don't divide, suggesting that these cells get mutated in a different way. Neurons' mutations seem to occur when the cells are making RNA and protein from their DNA. Genes that are busier in the brain had a higher risk of mutation, the team found. "It's like everything, really," Woodworth says. "Parts of your car that you use more heavily are more likely to wear out," she says.

The multitude of mutations found among neurons may have a role in brain disorders such as Alzheimer's disease, schizophrenia and autism. In their experiments, the researchers found mutations linked to schizophrenia and a seizure disorder in neurons from healthy people. It's unclear how many of the neurons in the brain need to harbor harmful mutations before a disorder appears. But these genetic changes aren't necessarily a bad thing: It's possible that some amount of genetic diversity helps the brain operate, McConnell says.

The results also offer a way to study how a human brain is built, Woodworth says. This detailed description of individual cells' genomes lets scientists trace the cells' lineages all the way back to the embryo, offering clues about the assembly of vastly different parts of the brain. Much of what scientists know about that comes from animal studies. This technique provides a way to do those experiments in people, Woodworth says. ■

HUMANS & SOCIETY

Bronze Age mummies found in Britain

Microscopic investigation uncovers once-preserved skeletons

BY BRUCE BOWER

Widespread mummification of the dead in ancient Britain has been kept under wraps — until now.

Microscopic bone studies indicate that bodies buried at sites throughout Britain were intentionally mummified during the Bronze Age, between about 4,200 and 2,750 years ago, say bioarchaeologist Thomas Booth of the Natural History Museum in London and colleagues.

Bones from 16 of 34 Bronze Age Britons exhibit little to no bacterial damage, Booth's team reports in the October *Antiquity*. A lack of such damage signals that natural or artificial mummification blocked rapid decomposition of a dead body's flesh.

The new findings "raise the question of how widespread such mummification might have been beyond Britain," remarks Martin Smith, a biological anthropologist at Bournemouth University in Poole, England.

At a time when ruling classes increasingly controlled farmland, "mummified bodies could be used to highlight an individual's lineage and legitimize claims to ancestral lands and rights," Booth says.

Mummification preserves soft tissue. In ancient Egypt and South America's Andes region, mummies were preserved in hot, dry climates that deprive tissue-destroying gut bacteria of moisture needed to survive. Britain's damp climate provides no bacterial protection. So any bodies mummified in ancient Britain would now be skeletons, unless the mummies were buried in watery bogs where a lack of oxygen kills gut bacteria.

In 2005, study coauthor Mike Parker Pearson of University College London led a team that reported the discovery of skeletal evidence that lacked bacterial damage, suggestive of Bronze Age mummification at a Scottish site.

In the new study, Booth's group examined two ancient mummies as an initial test of whether past mummification can be identified from skeletons. One individual's body had rapidly dried out in a desert in Yemen. The other had been found in an Irish peat bog.

Little bacterial damage appeared on a bone from the Yemeni body. Slightly more but still minimal bone destruction was found on the Irish body, which apparently started to decompose before being immersed in the bog.

Other researchers previously reported near or total absence of bacterial damage on the bones of 10 mummified people, including Ötzi the Iceman (*SN: 9/25/10, p. 14*), whose body was found frozen in the Italian Alps.

The results mean researchers can now identify cases of ancient mummification from bones alone, Booth says. "There is such a thing as a mummified skeleton."

Comparable signs of mummification characterized bones from 16 Bronze Age individuals studied by Booth's group. Included in this set were the bones from two graves at a site called Cladh Hallan on Scotland's Outer Hebrides islands that Parker Pearson studied in 2005. The new findings confirm Parker Pearson's initial report and extend the practice of Bronze Age mummification into central and southern England.

Parker Pearson and his colleagues had found that each of the two Cladh Hallan burials contained body parts from three different individuals. Radiocarbon dating indicates that those six people died several hundred years before being interred beneath a roundhouse around 3,000 years ago.

In contrast to "mummified skeletons," bones from bodies that have decomposed rapidly display extensive bacterial damage when examined under a microscope. So did nearly all bones — mainly upper-leg bones — from 35 individuals buried at British farming villages dating to before the Bronze Age and 183 people interred up to about 2,000 years after the Bronze Age, Booth's team finds. The few exceptions involved cases where factors such as dismemberment of body parts after death or treatment of bodies with lime probably deterred decomposition, Booth says.

This Bronze Age skeleton from England comes from a mummified body, a microscopic bone analysis indicates. The individual's curled up position is consistent with the body having been bundled and stored before being buried.

CAMBRIDGE ARCHAEOLOGICAL UNIT

It's hard to say for sure how Bronze Age Britons mummified dead bodies. Some bones with signs of mummification contain damage consistent with exposure to low-level heat. In these cases, bodies may have been dried out in smokehouses, Booth says. Bronze Age communities probably also mummified bodies in bogs and by removing internal organs of the dead, he says.

Storing the deceased above ground for long periods would have slowed decomposition, says biological anthropologist Christopher Knüsel of the University of Bordeaux in France. Several Bronze Age individuals identified as having been mummified were buried with their legs tucked under their chins, suggesting they had been bundled and stored somewhere before being placed in graves, Knüsel explains. Delaying burials for powerful individuals may have enabled extended funeral ceremonies and rituals aimed at reorganizing the Bronze Age social order, he speculates.

Says archaeologist Haagen Klaus of George Mason University in Fairfax, Va.: "Booth's paper opens a new window on interactions of the living with the dead in Bronze Age Europe." ■

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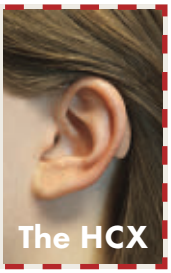

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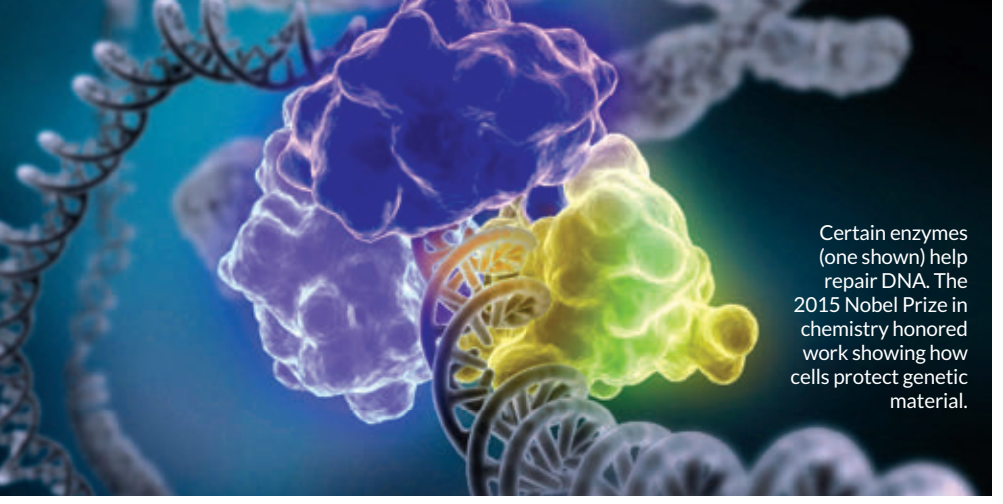


Certain enzymes (one shown) help repair DNA. The 2015 Nobel Prize in chemistry honored work showing how cells protect genetic material.

SCIENCE & SOCIETY

Nobels note neutrinos, DNA, drugs

Work on particle masses, gene repair, fighting disease honored

The Nobel Prizes in physics, chemistry and physiology or medicine ran the gamut this year, honoring both fundamental science discoveries and research with real-world impacts.

The physiology or medicine award went to three researchers who developed life-saving drugs. William Campbell of Drew University in Madison, N.J., and Satoshi Ōmura of Kitasato University in Tokyo won half the prize for their work on ivermectin, which combats roundworm infections. The other half went to Youyou Tu of the China Academy of Chinese Medical Sciences for her discovery of the antimalarial drug artemisinin.

"This is one of those Nobel Prizes for drugs that have truly impacted hundreds of millions of people, no exaggeration," says Anthony Fauci, director of the National Institute of Allergy and Infectious Diseases in Bethesda, Md.

In 1974, Ōmura discovered in the vicinity of a Japanese golf course a soil bacterium called *Streptomyces avermitilis* that makes a compound called avermectin. Campbell determined that the compound can kill some parasites' larvae. Avermectin was later tweaked to make ivermectin, an even more powerful compound that has helped eliminate river blindness in parts of Latin America and that treats debilitating elephantiasis.

In 1967, Tu and colleagues began combing through over 2,000 traditional Chinese herbal recipes and eventually found a compound in the sweet wormwood plant (*Artemisia annua*) that showed promise against malaria caused by *Plasmodium* parasites. After seeing artemisinin combat parasites in mice and monkeys, Tu tested it on herself.

Discoveries honored by this year's chemistry prize also have implications for health. Tomas Lindahl, Paul Modrich and Aziz Sancar identified molecular repair kits that cells use to fix damaged DNA. Without a way to correct DNA errors, damage would build up and trigger diseases such as cancer.

Understanding the details of DNA repair has been important for designing cancer drugs, says Laurence Pearl, a biochemist and structural biologist at the University of Sussex in England.

DNA is a fragile molecule that can be damaged by sunlight, toxic chemicals, radiation or even normal chemical reactions inside the cell. Lindahl, of the Francis Crick Institute in England, determined that DNA can fall apart on its own, even without injury. He described how a cell can remove and replace damaged DNA constituents.

Sometimes the cell makes mistakes while copying DNA. Modrich's work revealed how a cell can correct these genetic errors by replacing DNA's individual units. Modrich is a Howard Hughes Medical Institute investigator at the Duke University School of Medicine.

Sancar, of the University of North Carolina School of Medicine, uncovered some of the proteins responsible for patching up DNA after ultraviolet damage and how they work.

Capturing the identity-shifting behavior of neutrinos won Takaaki Kajita of the University of Tokyo and Arthur McDonald of Queen's University in Kingston, Canada, the physics prize. The scientists led giant underground experiments that revealed that the elusive particles morph from one variety into another.

Those findings demonstrated that neutrinos have mass, which confirmed many physicists' suspicions but defies the standard model, the framework that predicts the properties of nature's particles and forces.

Physicists knew that three types of neutrinos exist in nature: electron, muon and tau. In 1998, Kajita and his team at the Super-Kamiokande experiment found evidence that neutrinos produced in Earth's atmosphere switched identities before striking the detector, located under a Japanese mountain. Three years later, McDonald's Sudbury Neutrino Observatory collaboration discovered that some neutrinos emitted by the sun change type en route to Earth. *—Andrew Grant, Meghan Rosen, Tina Hesman Saey, Laura Sanders, Sarah Schwartz and Thomas Sumner*

2015 Nobel Laureates

PHYSIOLOGY OR MEDICINE

William Campbell
Drew University

Satoshi Ōmura
Kitasato University

Youyou Tu
China Academy of Chinese Medical Sciences

CHEMISTRY

Tomas Lindahl
Francis Crick Institute

Paul Modrich
Duke University School of Medicine

Aziz Sancar
University of North Carolina School of Medicine

PHYSICS

Takaaki Kajita
University of Tokyo

Arthur McDonald
Queen's University

COURTESY OF TOM ELLENBERGER/WASHINGTON UNIV. SCHOOL OF MEDICINE, VIA NIGMS

Read more in-depth coverage at **bit.ly/SN_Nobels2015**

ATOM & COSMOS

Salt streaks point to present-day water flows on Mars

Liquid water might not be a distant memory on Mars. New data suggest that water flows on the Red Planet even today. Seasonal dark streaks etched onto some slopes are coated with salts that need liquid water to form, researchers report online September 28 in *Nature Geoscience*. The Mars Reconnaissance Orbiter recorded spectra showing hydrated salts at four locations on Mars.

The salty trails appear annually, only in warmer seasons. Rising temperatures probably drive water to the surface, though whether the source is buried ice, local aquifers or something else is unclear. The salt may help keep the water liquid by lowering its freezing point, the researchers say. — *Christopher Crockett*

Salts deposited in dark streaks on Mars, such as these in the nearly 1,000-kilometer-long Coprates Chasma canyon, are left behind by seasonal water flows, a new study suggests.

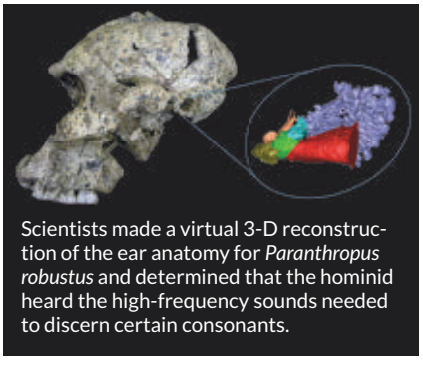
HUMANS & SOCIETY

Ancient hominid ears were tuned to high frequencies

South African hominids that lived between around 2.5 million and 1.5 million years ago had an ear for high-frequency consonant sounds, anthropologist Rolf Quam of Binghamton University in New York and colleagues report September 25 in *Science Advances*.

Using CT scans and digital technology, Quam's team reconstructed the ear anatomies of two *Australopithecus africanus* partial skulls and one *Paranthropus robustus* specimen. Modern human ear measurements guided virtual re-creations of soft tissue around ear bones, enabling calculations of audible sound frequencies.

A. africanus and *P. robustus* could have heard high-frequency consonants associated with the letters T, K, F and S better than either chimps or present-day people do, the team found. An ability to hear, and presumably make, these sounds enhanced communication among hominids foraging in groups across open landscapes, the researchers propose. Such communication need not have required a humanlike language, only vowel and consonant sounds with shared meanings, the researchers say. — *Bruce Bower*



Scientists made a virtual 3-D reconstruction of the ear anatomy for *Paranthropus robustus* and determined that the hominid heard the high-frequency sounds needed to discern certain consonants.

FROM TOP: JPL-CALTECH/NASA, UNIV. OF ARIZONA; R. QUAM

BODY & BRAIN

Sperm protein may offer target for male contraceptive

For 55 years, birth control pills have been exclusively for women. But men may be a step closer to getting in on the action, researchers report online October 1 in *Science*.

A newly identified sperm protein, called PPP3CC/PPP3R2, gives scientists a promising target for developing male contraceptives. The protein resides in sperm tails and helps sperm push through the tough outer membrane of an egg.

Blocking the protein with drugs for two weeks made mice infertile, though they were still able to mate. And just a week after stopping the drug treatment, fertility recovered. The researchers say that targeting the sperm protein in humans could lead to reversible, fast-acting birth control options for men. — *Meghan Rosen*

ATOM & COSMOS

Rocky layers reveal recipe for comet 67P

To make one oddly shaped comet, take two smaller comets and squish them together. That probably explains why comet 67P/Churyumov-Gerasimenko looks like a rubber duck, a new study reports.

Since the Rosetta spacecraft's arrival last August (*SN: 9/6/14, p. 8*), researchers have debated whether 67P is a comet that lost some weight around its waistline or two comets that got a little too attached to one another. Layers and terraces on cliffs gave away 67P's coupling. Mismatched layers between the comet's head and body imply that the two lobes formed independently and later fused together, Matteo Massironi, a geologist at the University of Padua in Italy, and colleagues report online September 28 in *Nature*.

The cliffs provide a peek at what passes for bedrock on a comet, revealing a stack of ice and dust coatings similar to strata seen in sedimentary rock formations on Earth. The strata in the head are slightly askew to those in the body. The researchers "do a lot of very clever work to trace these layers," says planetary scientist Michael Belton, president of Belton Space Exploration Initiatives in Tucson, Ariz. — *Christopher Crockett*

Noshing on nano

The tiny particles in what we eat raise big questions

By Susan Gaidos

It seemed like a small thing when Paul Westerhoff's 8-year-old son appeared, with his tongue and lips coated bright white. The boy had just polished off a giant Gobstopper, a confectionery made of sugary, melt-in-the-mouth layers. Curious about the white coating, Westerhoff, an environmental engineer, pored over the jawbreaker's contents and discovered just how incredibly small the matter was.

Among the Gobstopper's ingredients were submicroscopic particles of titanium dioxide, a substance commonly added to plastics, paint, cosmetics and sunscreen. At the time, Westerhoff's lab group at Arizona State University was actively tracking the fate of such particles in municipal wastewater systems across the nation.

Titanium dioxide is also a food additive approved by the U.S. Food and Drug Administration. Ground to teensy particles measuring just tens of billionths of a meter in size — much smaller than a cell or most viruses — titanium dioxide nanoparticles are frequently added to foods to whiten or brighten color.

Weeks after his son's candy-coated encounter, Westerhoff went to the supermarket, pulled more than 100 products off the shelves and analyzed their contents. His findings, published in 2012 in *Environmental Science & Technology*, show that many processed foods contain titanium dioxide, much of it in the form of nanoparticles. Candies, cookies, powdered doughnuts and icing were among the products with the highest levels. Titanium dioxide is also found in cheese, cereal and Greek yogurt.

Jawbreaker candies contain nanoparticles.

"I began to question why we care about things in the environment — at a few micrograms per liter in water — if we're freely ingesting these materials," Westerhoff says.

Titanium dioxide isn't the only nanoingredient added to food. Various other materials, reduced to the nanoscale, are sprinkled into food or packaging to enhance color, flavor and freshness. A dash of nano will smooth or thicken liquids or extend the shelf life of some products. Scientists have designed nanosized capsules to slip beneficial nutrients, such as omega-3 fish oil, into juice or mayonnaise, without the fishy taste.

Food scientists aren't stopping there. They are downsizing the structure of a wide array of ingredients with bold plans to help tackle obesity, malnutrition and other health issues (see "Nanocreativity," Page 20).

But as scientists cook up ways to create heart-healthy mayo and fat-fighting ice cream, some are also considering the potential risks that might accompany the would-be benefits. Because of their small size, ingested nanoparticles may interact with cells or behave differently than their bulkier

S. EGTS

counterparts. So far, less-than-perfect laboratory studies offer contradictory results.

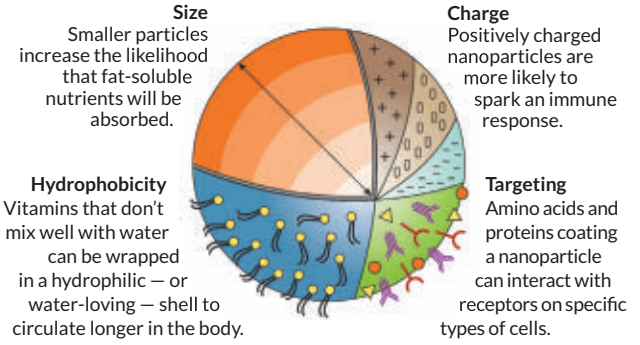
Researchers, including those developing nanofoods, say more information is needed on the ingredients' potential impacts. Current studies, limited to mice or lab dishes, often analyze megadoses of particles far beyond what any normal diet would include. Scientists need a better handle on what happens when people nosh on nanolaced foods daily, taking in small doses at a time, says Ohio State University pathologist James Waldman. He and others are devising tests to find out.

A pinch of nano

Over the last two decades, nano-sized components — smaller than 100 nanometers — have found their way into a wide range of products: clothing, electronics and cosmetics as well as food. But people have been exposed to, and have inevitably ingested, nanoparticles for much longer, says Andrew Maynard, director of the Arizona State University Risk Innovation Lab in Tempe. Since prehistoric times, people have been consuming nanoparticles found in natural foods such as milk (casein micelles, for example, are nano-sized particles that help calves readily digest their mother's milk). Nanoparticles also creep into the food supply from environmental sources. Burning wood, oil and coal; wildfires; volcanic activity; and crashing of ocean waves release ultrasmall particles of metal, carbon or silica into the atmosphere and into the food chain.

Even with this long history of nanoparticle exposure, Maynard says, it's highly unlikely that people had been eating the kinds of particles added to foods today. The distinction is important, he says. "Our bodies have always been exposed to nanoparticles, but they're now being exposed to different types. We just need to make sure that our bodies can deal with the ones we're putting in food."

What makes particles different today is not only their size, but also their specificity. The amino acids and proteins that coat a nanoparticle determine its shape and surface properties, which can enhance or reduce the particle's propensity to bind to certain molecules. By fine-tuning surface features, scientists can control where or how quickly nanoparticles release their contents.



Shaping behavior By changing a nanoparticle's size and surface characteristics, scientists can affect how the particle behaves in the body.

So far, only a few nanoingredients are added directly to foods or packaging: Titanium dioxide, silicon dioxide and zinc oxide are the most common. Larger versions of these ingredients have been used in food and medicines for decades and are considered "generally recognized as safe" by the FDA, which requires that any substance added to food be evaluated for safety.

Unexpected interactions

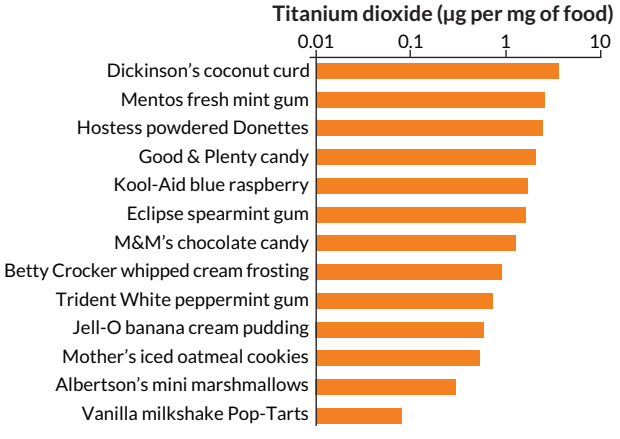
Scientists have developed numerous ways to test the safety of substances that go into food, but most of the tests were designed decades ago, before ingredients began to go nano. Titanium dioxide, for example, was evaluated in the late 1960s, using particles larger than 100 nanometers. Human cells were exposed to the substance to test for toxic effects and to work out how much of it can be safely consumed.

But those safety tests may not apply to some nanosubstances. Size and surface features can improve or impair a nanoparticle's ability to enter cells. Some nanoparticles — including those considered safe by the FDA — interact with cells in odd or unexpected ways, according to several recent studies.

One study, published in April in the journal *Small*, examined the effects of silicon dioxide, titanium dioxide and zinc oxide on cells taken from the human intestinal lining. At high doses — higher than most people would ordinarily consume — all three nanoparticle types damaged DNA, proteins and lipids in the cells. Zinc oxide proved to be the most toxic. Lower levels of exposure to nanozinc oxide impaired certain proteins, such as those that help cells repair DNA damage; higher levels of the substance led to cell death.

Though it's not yet clear if nanoparticles of these types would have toxic effects in the human gut, Gretchen Mahler of Binghamton University in New York says the findings show the difficulty of classifying a particular type of nanoparticle as toxic or safe. Many studies, she says, expose cells to very high levels of nanoparticles, focusing on the effects of

Whiter whites Titanium dioxide is found in many foods. Tests show that on average more than one-third of the titanium dioxide in foods is in the form of nano-sized particles. SOURCE: A. WEIR *ET AL*/*ENV. SCI. TECH.* 2012



T. BOREL AND C.M. SABLIOV/*ANNU. REV. FOOD SCI. TECHNOL.* 2014

Nanocreativity

Cristina Sabliov, a bioengineer at Louisiana State University, says food manufacturers are experimenting with loading tiny particles with nanonutrients and fine-tuning the surface of the particles to customize where and how the contents are released in the body. At the University of Massachusetts Amherst, food scientist David Julian McClements is building nanocrystals of proteins found in milk or derived from plants that can be loaded with beneficial components tailored to meet different needs. Among the items now in development:

Vitamins that hit the spot. Sabliov's lab is developing microscopic delivery systems for vitamins. For example, she is wrapping vitamin E within tiny spheres designed to travel unimpeded through the stomach's acidic environment before breaking down in the small intestine. Adding certain enzymes to a particle's surface allows it to adhere to cells in the intestinal wall for better absorption.

Food with less salt and sugar. Capsules of nanoparticles that dissolve in the mouth, latching on to the tongue's taste receptors to deliver bursts of flavor, may mean foods with less salt or sugar can still be tasty.

Nutraceutical delivery. To improve uptake of two nutrients that are hard for the body to absorb, lycopene and carotene, McClements is suspending them in liquid nanodroplets to deliver digestible doses in beverages, desserts and yogurts.

Suppress the appetite. To keep hunger pangs at bay and encourage people to eat less, diet foods are being fortified with nanoparticles that break down slowly, or that deliver peptides — such as pancreatic polypeptide or peptide YY — that signal fullness.

Age-specific foods. To deal with reduced stomach acid levels in the elderly, food products are fortified with vitamin-filled particles that break apart quickly in the presence of lower-than-normal levels of acid.

Beneficial bacteria. Food scientists are inserting teensy portions of probiotics into particles crafted to remain intact until they reach the colon. — *Susan Gaidos*

a few large exposures or looking for signs of extreme cellular stress or cell death. She questions whether those safety tests are appropriate for nanomaterials.

Mahler's lab group aims to pin down nanoparticles' more subtle effects on the intestine using amounts that a person might consume in a single meal or day. Rather than just examining whether the cells exposed to nanoparticles are alive or dead, she evaluates whether they function the same way as unexposed cells.

In a series of experiments, Mahler set out to see what happens in the gut after a steady stream of small doses, the kind you'd get if you were eating nanoparticle-enriched foods daily. Working with scientists at Cornell University and the U.S. Department of Agriculture, she developed a three-dimensional model of the intestinal tract, composed of the various cells that line the human gut. The scientists tracked the effects of polystyrene nanoparticles on the cells and on the intestinal linings of live chickens. Though polystyrene, a polymer, is not used in food products, Mahler says the particles were ideal for testing because they can fluoresce, making them easy to track once swallowed.

The results, published in 2012 in *Nature Nanotechnology*, showed that small doses of the polystyrene nanoparticles created changes in the fingerlike projections that cover the surfaces of the intestine-lining cells. These tiny structures, called villi, are important for absorbing nutrients. After initial ingestion of nanoparticles, iron absorption dropped by almost 50 percent. But in chickens fed over a period of two weeks, iron absorption rose about 200 percent. Over time, the villi became larger, allowing more iron to enter the bloodstream.

> "Particles are getting into the bloodstream, and once they're there, they can go to any other organ."
>
> JAMES WALDMAN

Mahler's lab used the same approach to study how nanoparticles of titanium dioxide and silicon dioxide influence nutrient absorption in human cells in the lab. Preliminary results from the studies, presented in March at the Society of Toxicology annual meeting in San Diego, indicate that titanium dioxide nanoparticles in the gut change the way iron is absorbed, and silicon dioxide nanoparticles alter zinc absorption. Mahler's group is working to piece together the mechanism by which these nanoparticles disrupt absorption in the small intestine.

Down the hatch

Most studies of nanoparticles in food focus on the gastrointestinal tract — the mouth, esophagus, stomach and intestines. Waldman's group at Ohio State is tracking the fate of nanoparticles once they're swallowed to see if they travel beyond the gut. In February, the researchers showed that nanoparticles force-fed to mice can reach the liver, kidneys, lungs, brain and spleen. Details were published in the *International Journal of Nanomedicine*.

"Particles are getting into the bloodstream, and once they're there, they can go to any other organ," Waldman says.

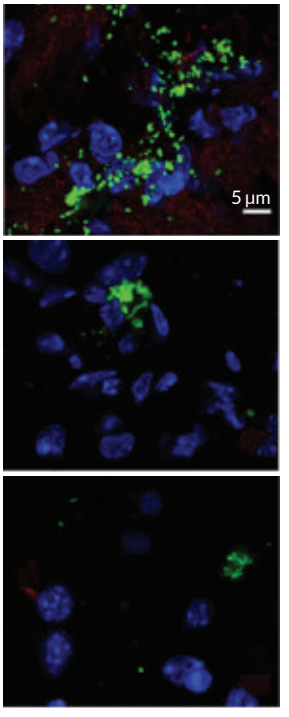
The findings were not entirely a surprise, he says. In earlier research, in animals fed different types of nanoparticles, the particles were later detected in organs. But previous studies relied only on crude methods, removing organs and digesting them in acid to look for the tiny particles.

To see where nanoparticles accumulate in live animals, Waldman's group created a nanoparticle filled with quantum

dots that fluoresce (*SN: 7/11/15, p. 22*). Working with Ohio State chemist Prabir Dutta, Waldman's group designed particles with outer shells nearly identical to a food-grade nanosilicon dioxide. Because the surface of the particle is what interacts with a cell, the scientists buried the fluorescent molecules inside the silica shell. By doing so, they could ensure that it was silicon dioxide — not the fluorescent tag — interacting with the cell.

The method allowed the scientists to see where the material goes once it enters the body and then count the number of particles actually absorbed. Waldman says that knowing the path that tiny nanoparticles take is essential for settling questions about their potential risk and impact on human health. Scientists need to know, for example, if a particle will be absorbed into the bloodstream and where it will travel. They also need to know if it will stay or be cleared.

Waldman's group plans to incorporate the fluorescent nanoparticles into the mice's chow so they consume them regularly in their food. Every few weeks, the scientists will run tests to see where the particles accumulate and assess the animals' tissues for inflammatory responses and nanoparticle-associated injury. The study will include newly pregnant animals to determine if the particles from food reach cells in the developing fetus.



Fluorescent nanoparticles (green) force-fed to mice found their way beyond the stomach (top) to the kidneys (center) and brain (bottom).

A. ZANE ET AL./INT. J. NANOMED. 2015

Chew on this

The FDA has not erected new hoops for food manufacturers that use nanoparticles. Requests to use a food ingredient at the nanometer scale are subject to the same safety requirements applied to other food additives, according to FDA press officer Megan McSeveney. Manufacturers must demonstrate that the substance is safe under the conditions of its intended use.

In June 2014, the agency issued guidelines that go only as far as advising manufacturers to consult with the government before launching nanotechnology products.

So food scientists who are developing futuristic applications are scrambling to assess the safety of their downsized substances. At the University of Massachusetts Amherst, food scientist David Julian McClements is creating nanoparticles using natural ingredients, such as casein micelles from milk or plant proteins, to encapsulate everything from vitamins and antioxidants to omega-3 fatty acids and probiotics.

Once they create a new particle, McClements and colleagues run a gamut of tests to see how the particle reacts in cells in the lab and in mice. Because the nanoparticles he studies are made from ingredients normally found in the human diet, the particles tend to break down during digestion in ways similar to foods. Such particles are expected to be safer than particles made of nonbiodegradable materials, such as titanium dioxide, McClements says. Still, such tests are needed before bringing new foods to the market.

Waldman and Mahler say that to realistically reflect what is happening with people, scientists need to conduct long-term studies, in both animals and people. By feeding animals low doses of a particle over several months' time, researchers should be able to spot potential problems.

"I would study the animal's overall health. If something specific is found, then you can zero in on that particular effect, that organ, that system," Waldman says.

Ultimately, epidemiological studies — designed to track peoples' intake of nanoparticle-laced foods over extended periods of time — would be most informative, the scientists say. The ideal would be to track large groups of people who consume many foods containing nanoparticles and those who eat fewer nanoparticles, monitoring their health over months or years.

Waldman says studies should include individuals with intestinal diseases and pregnant women — groups that could be more vulnerable to any potential effects. People who have inflammatory bowel disease — in which the intestinal wall is "leaky" — may be at higher risk of nanoparticles getting into circulation and reaching other tissues, he says.

Meanwhile, scientists agree that, based on studies to date, the nanofoods found on supermarket shelves are probably safe to eat — when consumed at "typical" quantities. A few nano-laced cookies probably won't do harm.

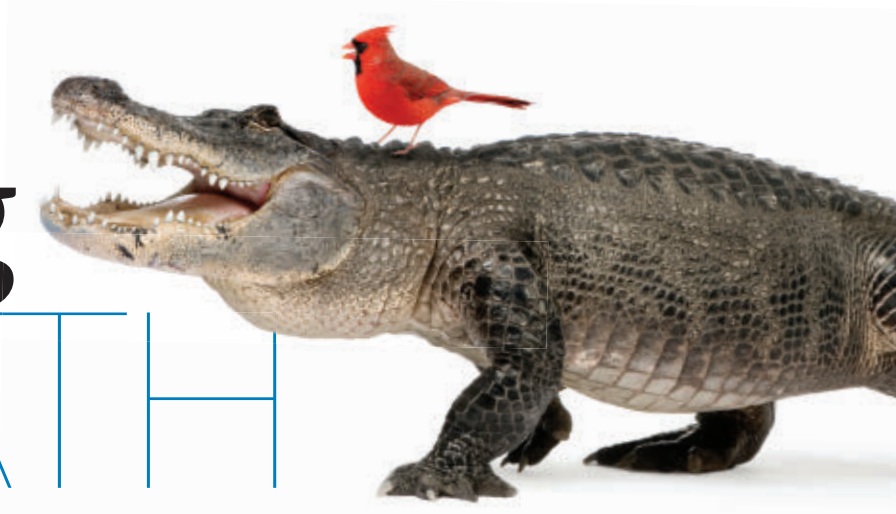
Waldman says he doesn't avoid eating foods containing nanoparticles. Westerhoff, whose son devoured the Gobstopper, agrees. Food nanotechnology actually makes food better, he says, "giving chocolate a smooth, creamy texture or preventing dry ingredients from clumping."

Still, skeptical consumers, who cannot always find nanoparticles listed on ingredient labels, want to be assured that the additives are safe. While nanotechnology offers new ways of transforming the features of food, creating safer, more nutritious fare, McClements says, scientists must find ways to demonstrate the safety of new types of nanoparticles before they are brought to market. "As with any new technology, you have to be cautious about how you use it and understand what's going on." ■

Explore more

- David Julian McClements. "Nanoscale nutrient delivery systems for food applications: Improving bioactive dispersibility, stability and bioavailability." *Journal of Food Science*. July 2015.

Chasing BREATH



Search for one-way airflow alters lung evolution story

By Susan Milius

Colleen Farmer was alone one night dissecting an alligator. Her focus was on blood flow in the heart, when suddenly, a hypothesis unfolded about animal lungs. In one sweep, she realized that what physiologists have assumed for decades about the evolution of airflow in alligators, other living reptiles, birds and maybe even dinosaurs might just be startlingly wrong.

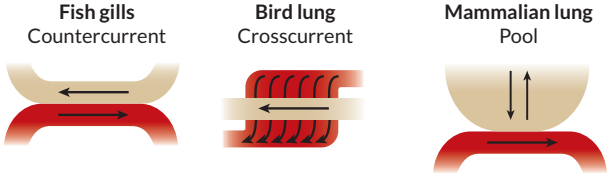
Lungs sound simple: Air goes in, air goes out. But, like breathing itself, lungs are easy to take for granted and full of unexpected puzzles. In her windowless lab at the University of Utah, Farmer pondered two basic questions: Which direction does air really flow in lungs, and how did it evolve that way?

In people, air flows like the tides. Inhale, and air whooshes in. Exhale, and the air recedes along the same path, depleted of oxygen and laden with waste gas. Physiologists have believed that other vertebrates share this basic two-way tidal flow — except for birds.

Birds' breathing was considered more efficient. There's no downtime while used breath clears out of airways to make room for the next inhalation. Once fresh air reaches the lungs, it flows in one direction through an intricacy of loopy tubes in the crucial zones where blood vessels swap out gases. The evolution of more efficient lungs, biologists have argued, helped birds develop the metabolically expensive lifestyle of aerial athletes. Birds keep their bodies warm, regardless of the environment, and launch themselves into the skies.

Where air meets blood In most fish, incoming aerated seawater (tan) streams through gills in the opposite direction from blood (red) flowing beside it. That works well for extracting oxygen from a fluid carrying low levels of the gas. Most bird lungs extract oxygen efficiently from air (tan) flowing at more of an angle to blood vessels, and mammal lungs flush air in and out of contact with blood vessels.

SOURCE: C.G. FARMER/*PHYSIOLOGY* 2015



There are no barrier gates or fleshy valves in bird lungs that create their remarkable one-way flow. Geometry does the trick. Quirky phenomena called "aerodynamic valves" steer air through open passageways, relying on the angles and shapes of the branching passageways.

What suddenly occurred to Farmer was that lungs of animals like alligators might have aerodynamic valves that no one had noticed. If alligators did breathe with a version of one-way lungs — and she had a hunch they would — then maybe so would other animals that neither fly nor maintain round-the-clock body warmth. If she was right, the notion that one-way lungs originated as athletic aids in birds was just a waste gas of a hypothesis.

In that extraordinary late-night moment, Farmer even thought of an alternative notion. As she described in the journal *Physiology* in July, one-way flow is important for gators and other ground-hugging lurkers too. "It's about better breath-holding," she remembers thinking.

The path of her idea from brain flash to a string of published papers has not been an aerodynamically smooth whoosh. Farmer has had to invent techniques for making measurements no one had made before, a messy process involving indoor conflagrations and theatrical supply companies. She has dealt with outright disbelief, skepticism and the intense pressures of success. Her story shows just how counterintuitive the evolution of "simple" lungs can be.

Beachfront breathing

From the beginning, the story of vertebrate lungs is full of twists, says functional morphologist Elizabeth Brainerd of Brown University. What looks like the simplest way for something to have evolved rarely turns out to be the case. And don't be misled by cartoons.

Caricatures of ancient fish crawling out of water onto shore have delivered plenty of speech bubbles of merriment. They conjure the appealing scenario that lungs evolved when gill-breathing fishes ventured into the terrible, suffocating air. "Wrong," Brainerd says.

"A fish definitely did not crawl out and evolve lungs and limbs," she says. These supposedly terrestrial traits arose tens of millions of years before any vertebrate colonized its first meter of beachfront. The creatures that eventually did

FROM TOP: CHASS3/ISTOCKPHOTO (BIRD); GLOBALP/ISTOCKPHOTO (ALLIGATOR); E. OTWELL

Alligators don't fly, but a late-night notion led a researcher to show gators and birds share a breathing strategy, raising questions about other reptiles' lungs.

the colonizing had lungs and limbs long before they nosed out of the water.

Air breathing is useful even in the water, and has arisen in some form at least 38 times among fishes, Brainerd notes. When water goes stagnant, animals that can dart to the surface for a gulp of aerial oxygen are more likely to survive. And lungs are just one of the options for aquatic air breathers. Fishes developed reservoirs inside their mouths and above their gills. Some just swallow bubbles of air that release oxygen to blood vessels in the intestines before exhaling anally.

Air breathing proved vital to surviving on dry land but that's not what was important in its origins, Brainerd emphasizes in an overview of lung history that she wrote for the book *Great Transformations in Vertebrate Evolution*, published in July. Many of the great events in vertebrate history, such as leaving a water world for a dry one, relied on anatomy or physiology that had already evolved. But she cringes at overemphasizing the already evolved features as preparations, sometimes even called "preadaptations," for some great change to come. Ancestors had simply adapted to where they lived. There was no anticipation of where they might go. Evolution, she says, "has no intentionality."

Outsider science

Farmer's unusual idea about evolution in lungs may have sprung from her unusual background. "I feel like an outsider in biology," she says. As an undergraduate at the University of Idaho, she majored in physics and then worked at Lawrence Livermore National Laboratory on storage of spent fuel elements for nuclear reactors. "Oftentimes I feel like an impostor."

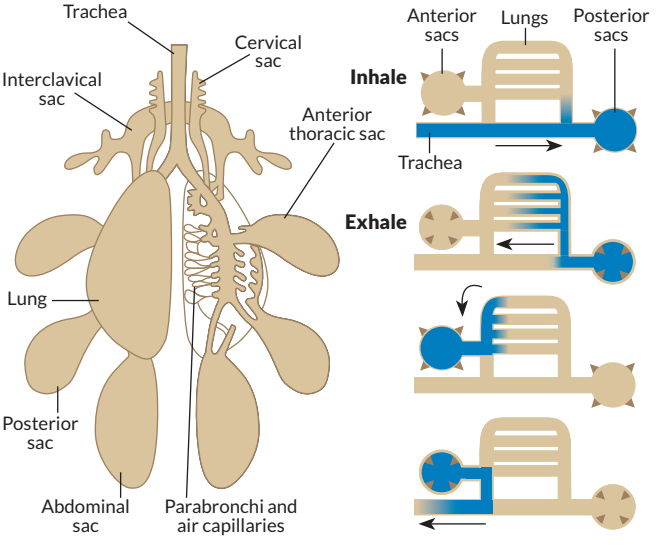
Still, doing physics trained her in problem solving and was important for studying air streaming through lungs. "I think I probably had a bit better understanding of fluid dynamics than your typical biology major," she says.

After five years in a big team, she yearned to test her own ideas. "It's the scary part, it's the hard part, but it's also the exciting part of being able to do research," she says. So she went to grad school, studying comparative physiology at Brown. A professor encouraged her to test her dogma-challenging notion about blood-flow patterns in two air-breathing fish: spotted gar and bowfin. "I've been thinking about hearts and lungs for half my career," she says.

Her Utah rethink of alligator lungs came to her in an instant. But persuading the National Science Foundation to fund her development of new techniques for the work "took forever," she remembers. Her grant proposals were "getting reviews that basically said, 'We don't believe you.'" She borrowed equipment, funded what she could personally, collected more measurements and kept submitting grant proposals.

Farmer planned to measure airflow by implanting flow sensors in live animals. Finding live alligators wasn't hard, as long as she was willing to drive from Salt Lake City to the Rockefeller Wildlife Refuge along the Louisiana coast. She learned to pack small young American alligators in pillowcases. It keeps them "quiet and calm" for the drive back to Utah, she says. However, when she gets to the hotel, "they stay in the car."

Alligator lungs don't have some of the showier features of bird lungs. Gators don't grow the big, flexible air sacs that pouch outward from the top and rear of lung structures, like a fringe of balloons. Many biologists have long assumed that these air sacs are what give bird-breathing its one-way route. In broad outline, when the bird inhales, air rushes down a large passageway that divides. Some air pushes immediately through a bank of skinny tubes less than 2 millimeters in diameter, where blood vessels give up their waste carbon dioxide and refresh their oxygen. The rest of the incoming fresh air sweeps into ballooning rear air sacs. The rear sacs contract and shoot the remaining air through the tiny tubes. Air leaving the tubes streams into air sacs toward the front of the lung, which are positioned so they can puff out the spent breath through the



Bird breath In a typical bird lung (left), air sacs balloon off the sides of the central zones where blood vessels swap gases with incoming fresh air. A schematic (right) shows how air (blue) flows one-way through the gas-exchange zone despite in-and-out flow elsewhere. Inhaled airflow divides, with some flowing into skinny tubes for gas exchange with entwining blood vessels and some entering rear sacs. The sacs then squeeze their air into the skinny tubes, which then release oxygen-depleted air into forward air sacs, which push the used air out through the trachea. SOURCE: D.W. LINZEY/*VERTEBRATE BIOLOGY*, 2ND EDITION, 2012

FROM LEFT: S. EGTS; E. OTWELL

mouth-nostril front of the air passage. Aerodynamic valves prevent blowback into the oxygen-exchange tubes.

Alligator lungs may not have the same ballooning air sacs dangling from them, but their large airways loosely share some geometry with bird lungs. To see if that geometry by itself could create unidirectional flow, Farmer tested five live alligators using borrowed small sensors that can detect airflow.

Testing, testing

She remembers the first time sensors gave her a reading that air flows one way over the blood vessels in an alligator lung: "It was simultaneously exhilarating and scary," Farmer says. "If I published something like that and it was wrong, it would be 'cold fusion' all over again. My career would be over." (The University of Utah, where Farmer works, was ground zero for the exaltation and subsequent implosion of the 1989 claim that Utah chemist Stanley Pons and a colleague had achieved nuclear fusion at room temperature.)

Intensifying the pressure, NSF finally funded her — on her fifth attempt — in 2008. To see if her initially encouraging results were just artifacts of the sensors, Farmer tried a different method to test flow direction borrowed from 1940s research on bird lungs.

An ingenious professor at the University of Groningen in the Netherlands, E.H. Hazelhoff, had examined a lung from a dead crow and sluiced a soup of starch grains in clear liquid through the airways. Air and liquids follow the same laws of fluid dynamics, he pointed out in a 1943 paper. He calculated that water moving at roughly one-fifteenth the speed of air, to compensate for water's greater density, should take the same path through a lung that air does. To trace that path, he created a little viewing window in the bird to reveal the lung and watched which way the pale starch dots moved.

Farmer tried the technique on a dead alligator, and was surprised when it worked. "I filled up a lung with water and cornstarch, and sure enough, I could see these little particles of cornstarch moving" the same way during simulated inhalation and exhalation. To submit the work to *Science*, she traded the down-home cornstarch for glowing microspheres. *Science* published the alligator paper in 2010, reporting that aerodynamic valves created one-way flow near blood vessels in alligator lungs.

As in birds, aerodynamic valves let gators move air in and out of the same tubing at the very front end of their respiratory passages while preserving that one-way flow through tubular structures within the lung (*SN: 2/13/10, p. 11*). "Absolutely transformational," Adam Summers of the University of Washington's Friday Harbor Laboratories said at the time.

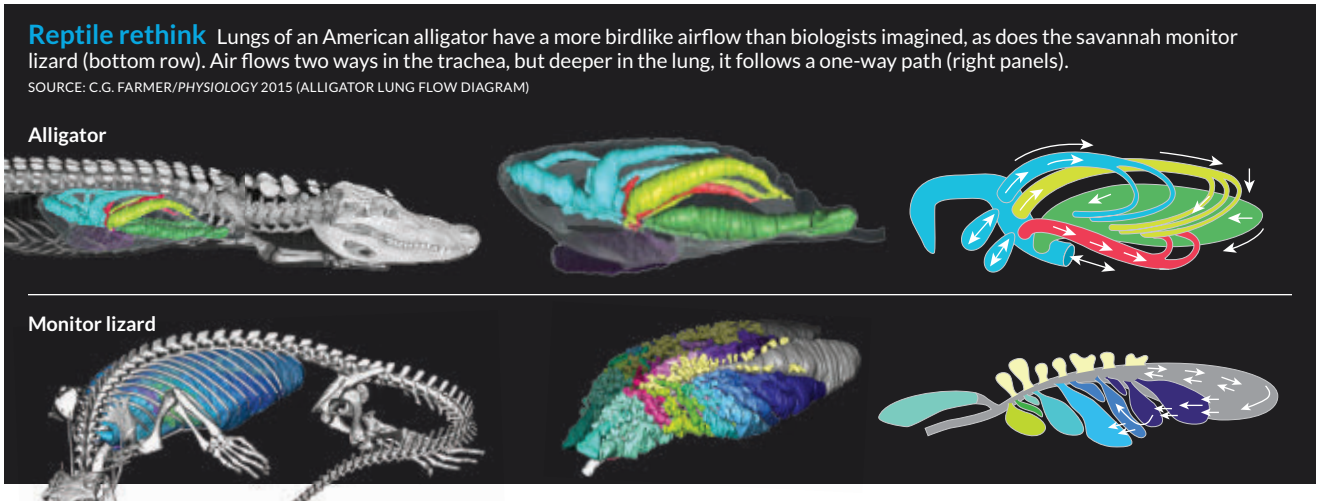
The result was surprising, but Farmer wanted to take an even more ambitious look at reptiles. On the tree of life, alligators belong to the closest living branch to birds, the crocodilians. With just an alligator and a bird, it was difficult to guess whether their ancestors had evolved one-way breathing independently or had inherited the fundamentals from some even more ancient common ancestor. Showing one-way flow in more distantly related species would suggest that an even bigger shift in thinking was needed.

So Farmer and her colleagues began testing airflow in reptiles not as closely related to birds, including a monitor lizard and the green iguana. But that required some doing.

"The techniques we were using in alligators didn't work very well in the iguana," Farmer says. In the narrow passageways of alligator lungs, sensors picked up a decent percentage of air flowing by. Iguana lungs have big open chambers, so sensors sampled only a small portion of the air. "Our signal-to-noise ratio was terrible," she says. Time for a new method.

She tried building little pressure sensors that she hoped would be more sensitive than the previous flow meters. But they were too difficult to use. So she turned to endoscopes like those used by veterinarians. By inserting a scope into iguana lungs, she hoped to watch air currents sweep along particles. But first she had to find the right kind of particles and capture and direct them into the lung efficiently.

"I was burning paper, trying to get little particles of soot," she says. "We tried cigarette smoke, which was just a nightmare."



Reptile rethink Lungs of an American alligator have a more birdlike airflow than biologists imagined, as does the savannah monitor lizard (bottom row). Air flows two ways in the trachea, but deeper in the lung, it follows a one-way path (right panels).
SOURCE: C.G. FARMER/*PHYSIOLOGY* 2015 (ALLIGATOR LUNG FLOW DIAGRAM)

ALLIGATOR, FROM LEFT: C.G. FARMER AND KENT SANDERS/UNIV. OF UTAH; E. OTWELL; LIZARD: E.R. SCHACHNER *ET AL/NATURE* 2013

What eventually worked was disco fog, specifically Froggy's Fog Swamp Juice, from a theatrical supply company.

A fog machine turned the swamp juice lipid mix into persistent spooky clouds that were hard to control. So a student suggested vaporizing the liquid in an e-cigarette. "I didn't even know what one was," Farmer says. But the portable device, easy to hook to tubing, produces just the amount of smoke she needs. No more disco fog filling the lab.

With these technical advances, Farmer and her colleagues reported in 2013 that air flows unidirectionally through lungs of a monitor lizard (*Varanus exanthematicus*). In 2014, the green iguana joined the list (*SN: 12/27/14, p. 12*). Neither animal has a lung structure much like a bird's.

Blow back

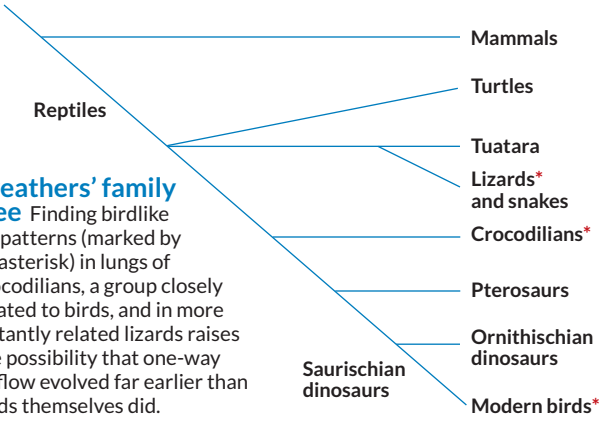
The papers shook up lung science. Even the first, on monitor lizards, was "truly shocking," says vertebrate paleontologist Mathew Wedel of Western University of Health Sciences in Pomona, Calif.

"And then the iguana results came out, and they're just ridiculous," Wedel says. (That's "ridiculous" in a good way.) Scientists have assumed that lungs have to be complex and highly subdivided to create the geometry of aerodynamic valves, but iguanas manage with a tube and a sac. Reading that paper was "like finding out that your kid's tricycle can go 200 miles per hour."

"Initially skeptical" is how John Maina of the University of Johannesburg in South Africa describes his reaction to the notion of widespread unidirectional flow. He has been studying respiratory structures for 36 years and didn't expect lungs without the big air sacs of a bird's lung to generate true unidirectional movement. But he has now read several of Farmer's papers and listened to her give a talk. "The science is sound," he says.

Steven Perry of the University of Bonn in Germany welcomes the papers as "extremely important," although he argues with some of Farmer's comparisons between features in birds and other species. A longtime analyst of reptile lungs, Perry has described holes between lung chambers that might allow unexpected circulation, but he didn't argue for one-way flow. It's still too early, he says, to call the holes in alligator lungs "parabronchi" like the features that enable one-way airflow in birds.

Farmer's work also has implications for longtime comparisons with dinosaurs. For Wedel, they are bittersweet. "I spent roughly the first decade of my career looking for evidence of birdlike air sacs in dinosaurs," he says. Basing that work on the old accepted wisdom, he thought he needed to find sacs, which would indicate that dinosaurs must have had birdlike airflow in their lungs. But reading Farmer's work convinced him that he had been working under two wrong assumptions. Reptiles do not in fact need the big air sacs to streamline their airflow. Nor would the presence of one-way flow reliably indicate a metabolically expensive lifestyle like that of birds.



Breathers' family tree Finding birdlike air patterns (marked by an asterisk) in lungs of crocodilians, a group closely related to birds, and in more distantly related lizards raises the possibility that one-way airflow evolved far earlier than birds themselves did.

Finding one-way airflow in such diverse reptiles supports Farmer's original notion that something was missing in the story of lung evolution. Alligators, monitor lizards and green iguanas — unlike birds — don't fly and don't rev up frantic metabolic rates to maintain a constant, warm body temperature. So, contrary to accepted thinking, perhaps unidirectional airflow is also important for the cold and slow lifestyle.

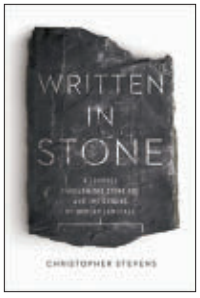
Reptiles are mostly ectotherms, animals that rely on their environment to warm or cool them. Ectotherms spend most of their lives holding their breath, Farmer says. Many hunt by just sitting and waiting. And animals can hide from prey or predators by freezing as still as stone. One-way airflow suits them. In stillness, a one-way breather can rely on the beating of its heart to jostle gases in the lungs enough to mix layers of air. And that jostling increases oxygen transmission from breath to blood vessel over what would occur by diffusion without mixing. Lungs that are shut tight during breath-holding can keep up the gas exchange more readily if air is just circulating one way, Farmer contends.

One-way air circulation may also ease the disposal of depleted air from the lungs, the process called washout, Farmer says. There's less mixing of old and fresh breath, and thus less need for as many breaths. Less urgency in breathing can bring many economies, such as less loss of body moisture or heat.

True, one-way airflow appears to benefit today's birds. Migrating geese can soar at low-oxygen heights and fish-hunting penguins can hold their breath on long dives for dinner. But way before such athletics evolved, some slow, chilly advantage might have driven one-way flow in their reptile ancestors. Today's benefits don't have to be yesterday's. As Brainerd says, evolution has no intentions. ■

Explore more

- Colleen G. Farmer. "The evolution of unidirectional pulmonary airflow." *Physiology*. July 1, 2015.
- Kenneth P. Dial, Neil Shubin and Elizabeth L. Brainerd, eds. *Great Transformations in Vertebrate Evolution*. University of Chicago Press, 2015.



Written in Stone
Christopher Stevens
PEGASUS BOOKS, $27.95

BOOKSHELF

An amusing romp through word histories

All these words we speak arose somewhere. But what do *acrid*, *acme* and *acrophobia* have in common? They all derive from the ancient Indo-European word *ak*, which meant sharp, quick or high and pointy.

Imagine such a language, sprinkled with onomatopoeia. *Ak* sounds sharp. *Mei*, the ancient word for smile, goes nicely with the facial expression used in saying it. In English, *mei* lingers on in things that make us smile, like a miracle or a mirror. The ancient opposite was *wa*, a crying sound that meant empty. It's still present in want, to be without.

In *Written in Stone*, journalist Christopher Stevens traces root terms from *ak* to *wid*, providing anecdotes as guideposts. The old word *ten*, for example, harks back to nomadic times, when tents provided movable towns for people pursuing a herd. These were light shelters made of animal skins stretched tight. In Latin, *tendere* meant "to stretch," as in tendering an offer. In Gaelic, *tana* meant flimsy and stretched out, not far from the old English *thynne*, or thin. Tents were worthless if not pegged down, and today "to hold" in French is still *tenir*. Tentacles hold things, as does anyone with tenacity.

Just when this glossary of a book seems to grow long, the reader finds a dandy word such as *spek* — which was all about seeing things. Looking closely can reveal a speck, but you might need spectacles. "If people look up to you, that's respect," Stevens notes. "If they look askance, that means they suspect you." It's a matter of perspective.

But wait, there's *mor*. The Indo-European word meant grief, and it traces to *mortality*. Then comes *moribund*, *morgue*, *postmortem*, *mourning* and even some remorse.

A true etymologist might see this as so much old news, but Stevens puts Sanskrit, Latin and Greek to good use as bridges to modernity. For instance, the ancient word *rud*, meaning red, found its way into Latin as *rudis*, or raw — like red meat. The smiley word *mei* acquired an "s" long ago in Sanskrit, where *smayate* translates as "he is smiling."

But Stevens can be Anglocentric. He refers to the ancient word *arg* as shiny, like some metals. Fair enough, but then he cites *argent* as an archaic English word for silver. Actually, it's from the Latin *argentum*. And in France, *argent* still means money.

As for *wid*, this archaic word morphed into *wise*. In Germanic languages, wits were essential to get by, lest you lose them. One who saw things clearly in old English was a witness. And as "w" became "v" in Latin, *wid* led to *videre*, to see. That led to *visible* and the video world we live in. As for the Greeks, they shortened *wid* to *-id* and came up with idea, a different kind of vision. — *Nathan Seppa*

SCREENTIME

Zippy videos teach chemistry of everyday life

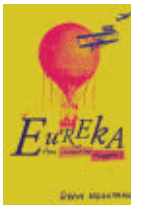
Two molecules give Sriracha hot sauce a fiery flavor by tripping a cellular alarm in the mouth that usually signals blazing-hot foods above 42° Celsius. When guacamole goes from a delectable green to an icky brown, it's forming the pigment melanin, which also tints human skin. And there's scientific truth to being hangry — a hunger-induced rage, possibly fueled by inferior breakfast foods.

These and other chemistry-based explainers and tips appear in breezy — and at times a bit cheesy — YouTube videos from the American Chemical Society in a series called Reactions: Everyday Chemistry. Each lighthearted episode turns the mundane into peppy chemistry questions you didn't even know you wanted answered. This includes how to ditch the smell of a skunk-sprayed dog and why silver compounds are shot into the air along with water to make unseasonably snowy ski slopes.

An episode in a chemistry video series explains why compounds in Sriracha hot sauce and other spicy foods register as heat to the mouth.

The series releases an episode about every week and has been going for more than a year, giving new watchers plenty to dive into. — *Beth Mole*

BOOKSHELF



Eureka
Gavin Weightman
A journalist describes the development of five 20th century inventions, drawing connections among the amateurs who devised the airplane, the bar code and the mobile phone. *Yale, $30*

The Mushroom at the End of the World
Anna Lowenhaupt Tsing
An anthropologist explores the Anthropocene through the experiences of people who forage, buy and eat the matsutake, a prized mushroom. *Princeton, $29.95*

Buy Books Reviews on the *Science News* website include Amazon.com links that generate funds for Society for Science & the Public programs.

TELEVISION

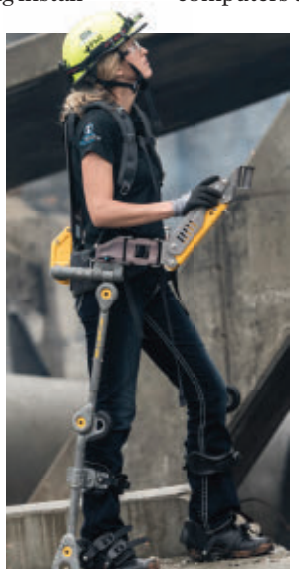
Hollywood-produced science documentary series comes to TV

A new series puts Hollywood's stamp on innovative science, with interesting results.

Premiering November 1 on the National Geographic Channel, *Breakthrough* is a series of six hour-long installments, each directed by a different Hollywood talent. The episodes, covering topics from aging to water, each highlight work from a few scientists. *Science News* got a sneak peek at the first three episodes.

In the first hour, "Fighting Pandemics," director Peter Berg explores the West African Ebola epidemic. Berg uses dripping blood to illustrate the spread of the disease, exploiting the shock value of Ebola's scariest symptom (even though bleeding happens in only a minority of patients). The film spotlights researchers' efforts to create a heat-stable Ebola vaccine and to find the most potent antibody cocktail to fight the virus. Also featured is Ian Crozier, an American doctor who was infected with Ebola while volunteering in Kenema, Sierra Leone. After his recovery, Crozier's left eye changed color due to a continuing Ebola infection.

While Berg uses gore and fear tactics to frame the fight against viruses, actor Paul Giamatti brings a sense of innocence and wonder to his exploration of cyborgs in "More Than Human." Giamatti is the only director in the first three episodes to appear on camera. He learns to think a rubber hand is his own and gets a taste of how exoskeletons (one shown below) may help people do their jobs. He also learns how researchers such as Duke University's Miguel Nicolelis are forging links between human brains and computers that give people control over robot arms and may one day help paraplegics walk again. Giamatti's take on the science is personal, sometimes goofy and engaging.

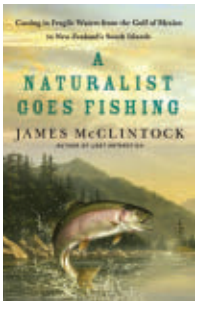


GARY S. CHAPMAN/NATIONAL GEOGRAPHIC CHANNELS

Breakthrough
PREMIERES NOVEMBER 1
NATIONAL GEOGRAPHIC CHANNEL

"Decoding the Brain," directed by Brett Ratner and narrated by Adrien Brody, explores how scientists are using electrodes and imaging techniques, such as MRI, to probe the inner workings of the brain, consciousness and memory. Ratner weaves personal stories — from the first scientist to get an MRI of his own brain and from patients undergoing brain mapping to pinpoint the source of their epilepsy — together with cutting-edge science in an entertaining and fascinating hour of television.

Other installments will include Ron Howard looking at aging, Akiva Goldsman tackling alternative energy and Angela Bassett exploring solutions to water problems. Judging from the first three episodes, each director is likely to bring a personal touch to the project. Science isn't cookie-cutter, and neither is this documentary series. — *Tina Hesman Saey*



A Naturalist Goes Fishing
James McClintock
ST. MARTIN'S PRESS, $25.99

BOOKSHELF

Chronicles of a lifelong love of fishing

In *A Naturalist Goes Fishing*, James McClintock shares personal stories of the decades-long avocation that helped steer him into a career as a marine biologist. It hasn't always been idyllic frittering away a warm summer's day on the banks of a lazy river.

In Antarctica's cold, where fish have natural antifreeze in their blood, McClintock accompanied other researchers as they angled for giant Antarctic toothfish by dropping a 450-meter-long line through a meter-wide hole drilled in the sea ice about five kilometers offshore. And in the Bahamas, while he was snorkeling with his ecology students, a moray eel mistook a glint from his wedding ring for a small fish and nearly ripped his finger off.

From his native Alabama to remote locales in New Zealand and Costa Rica, McClintock takes the reader on fascinating trips. He has angled for small fish using hand lines (no fishing pole, only hooks and bait), and he has sought to catch huge blue marlin with a rod and reel holding more than a mile of fishing line.

McClintock's tales of adventure and occasional misadventure are chock-full of details about fish and their ecology, along with vivid descriptions of his surroundings and experiences. Among folksy anecdotes about his boatmates and the types of bait they're using, he slips in facts about the threats that fish face worldwide — habitat loss, ocean acidification, oil spills and overfishing, to name just a few.

He also outlines efforts to save fish. For instance, many billfish such as blue marlin once ended up at the taxidermist, but today about 97 percent of blue marlin landed by recreational fishermen are released back to the sea. Studies show that fish survive catch and release, a practice that McClintock often follows both in freshwater and at sea, more often than many anglers believe.

As you read McClintock's riveting accounts and imagine the thrill of the fish on the line, you barely realize how much information you're soaking up. Don't throw this book back. It's a keeper. — *Sid Perkins*

SSP alumna Heidi Williams studies the economics of innovations in health care at MIT.

SSP alumna named MacArthur Fellow

Heidi Williams, a 1999 Intel International Science and Engineering Fair finalist, was named to the newest class of MacArthur Fellows in September. Williams is an assistant professor in economics at MIT and will receive a $625,000 stipend paid out over five years. Her work looks at the effects of patent policies and technology on medical research and health care. Williams joins at least 12 other SSP alumni who have received a MacArthur Foundation "genius" grant.

Kate Travis, deputy managing editor, digital, accepts ONA's award in Los Angeles.

Science News wins for 'Martian Diaries'

In September, the Online News Association honored *Science News* with best feature for a small organization. The award was for "The Martian Diaries: What If the Curiosity Rover Kept a Scrapbook?" (*SN: 5/2/15, p. 24*). Contributing correspondent Alexandra Witze wrote the piece, which was edited by Cori Vanchieri. User experience designer Federico Castaneda, creative director Stephen Egts, assistant art director Erin Otwell and digital editor Kate Travis transformed the print version of the story into a polished, interactive online feature. Judges called the piece "an out-of-this-world idea perfectly executed."

Launched in 2000, ONA's online journalism awards honor excellence in digital journalism.

Support the Society on Give to Science Day November 9

The Society for Science & the Public will celebrate its annual Give to Science Day on November 9. This 24-hour online fundraising effort supports SSP's mission to promote the understanding and appreciation of science and the vital role it plays in human advancement. In the last four years, Give to Science events have helped SSP raise more than $28,000 from over 600 donors.

We rely on your support to deliver award-winning journalism through *Science News* and *Science News for Students* and to help SSP continue to build the impact of our renowned competitions and educational programs.

In addition to donations, we're seeking photographs that show how our members give back to science — whether that's by teaching, doing research, designing inventions, participating in or supporting science fairs, mentoring young scientists or even just capturing everyday scenes of science in action.

Get involved by donating to our Give to Science Day fundraising effort at bit.ly/Give2Science, submitting your science-themed photos to ssp@societyforscience.org or posting on social media using the hashtag #Give2Science.

AUGUST 8, 2015

AUGUST 22, 2015

Delightful diatoms

After seeing **Sarah Schwartz's** "Encased algae create kaleidoscope of color" (*SN: 8/8/15, p. 32*), reader **John Turner** pointed out that diatom arrangements are part of a long tradition. "Amateur naturalists in Victorian times collected diatoms the way we today collect seashells and then would proudly show off their collections (under microscopes) to guests," he wrote.

KLAUS KEMP

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Behold the pentaquark

Quarks, the building blocks of protons and neutrons, travel in packs. Researchers at the Large Hadron Collider near Geneva caught a glimpse of two new five-quark particles, ***Andrew Grant*** *wrote in "LHC reports pentaquark sightings" (*SN: 8/8/15, p. 8*).*

"In the story, particle physicists at the LHC report that a pentaquark contains a charm quark and its antimatter counterpart," **Terry Breen** wrote in an e-mail. "Doesn't the theory of matter call for a particle and its antimatter counterpart to immediately annihilate each other?"

The discovered pentaquarks exist for only a little more than a trillionth of a trillionth of a second before decaying into other particles, **Grant** says. As for why they don't annihilate themselves before that, a few factors are at play.

First, the charm and anticharm quarks may not be right next to each other within the pentaquark. Also, in addition to having flavor — charm, strange, up, down, bottom or top — quarks also have a property called color, though it has nothing to do with the colors of the rainbow. If the colors of the charm and anticharm don't correspond, they take longer to annihilate.

Detecting consciousness

*In "Locked inside" (*SN: 8/8/15, p. 18*),* ***Laura Beil*** *relates the story of a man who, before regaining the ability to move and communicate with his eyes, lived for 12 years mentally aware but unable to interact. "Scientists assume that stories like these, astonishing as they are, represent only a small fraction of patients,"* ***Beil*** *wrote in her story exploring how scientists are learning to communicate with locked-in patients.*

Brian Quass took issue with the assumption about the low fraction. "For scientists to claim that such incidents are rare at this early point in the investigation (after all, locked-in syndrome has scarcely been discovered) strikes me as a mixture of defensiveness and wishful thinking," he wrote.

Neuroscientist **Damien Gabriel** of the University Hospital of Besançon in France replies that there are "strong clues" that most vegetative patients are not conscious, including that many patients lack even elementary reflexes. "In this case, chances of having preserved cognitive abilities are extremely poor," he says.

Another indicator is the severity of brain damage. "More than half of the brain is sometimes missing," he says. Neuroscientist **Srivas Chennu** of the University of Cambridge agrees that science still has a lot to learn about vegetative patients: "Exactly which parts and functions of the brain are important for consciousness is indeed a fascinating question, and a topic of current research."

A snake with legs

A four-legged snake fossil may demonstrate the evolution of snakes from lizard-like ancestors, ***Meghan Rosen*** *reported in "Snake fossil with four limbs found" (*SN: 8/22/15, p. 10*).*

Readers wondered about the animal's actual identity. "If it's not a snake, does this mean there was some other long, slinky, multiribbed species that just happened to resemble a snake?" asked **Mark S.**, noting that many of today's lizard species actually lack legs. Another reader, **hschulsinger**, wondered if the fossil might even be a hoax: "The 'legs' are too far apart to have been of any use to this creature."

The fossil may not have been a snake or even a reptile, **Michael Caldwell**, a paleontologist at the University of Alberta in Canada, told **Rosen**. "There are buckets of vertebrates out there that are long and skinny," he says. The animal could have been an amphibian, for example. Scientists have found lots of bizarre-looking ancient creatures, he says.

And although the animal's tiny limbs may not have been for walking, they could have helped it seize prey or grasp onto mates, the study's authors suggest.

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‘Whalecopter’ drone swoops in for a shot and a shower

This drone’s-eye view captures two humpback whales blowing a net of bubbles around their prey. Yet portraiture is only half of what whale-watching drones can do.

The remotely controlled hexacopter (left) that snapped this image off the New England coast last summer can also swing down to catch samples of spray that whales spout when they surface. The spray carries microbes, DNA and hormones that can expose a whale’s health and history.

Michael Moore, a whale biologist and veterinarian at the Woods Hole Oceanographic Institution in Massachusetts, says the snap-and-sniff idea grew out of puzzling over photos of individual whales. “The biologist in me looks at the image and says, ‘It’s fat,’ but the veterinarian wants to know why,” he says. So Moore and his colleagues use a drone to take pictures of, and then catch the blow from, a single whale.

Adapting a hexacopter for whale watching has its challenges. Drones check the ground to determine which way is up, but that doesn’t work on the pitching deck of a ship. And Federal Aviation Administration regulations often require that operators of research drones have regular pilot licenses.

Tests in July proved successful, the team reports. The drone snapped pictures from about 40 meters above the surface and then dipped to three meters for a breath of whale. — *Susan Milius*

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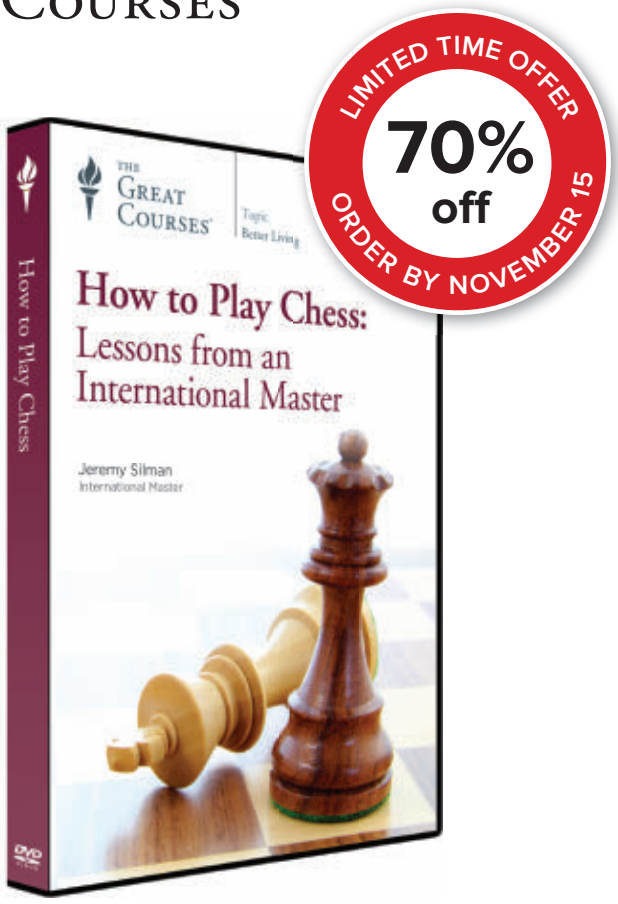

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