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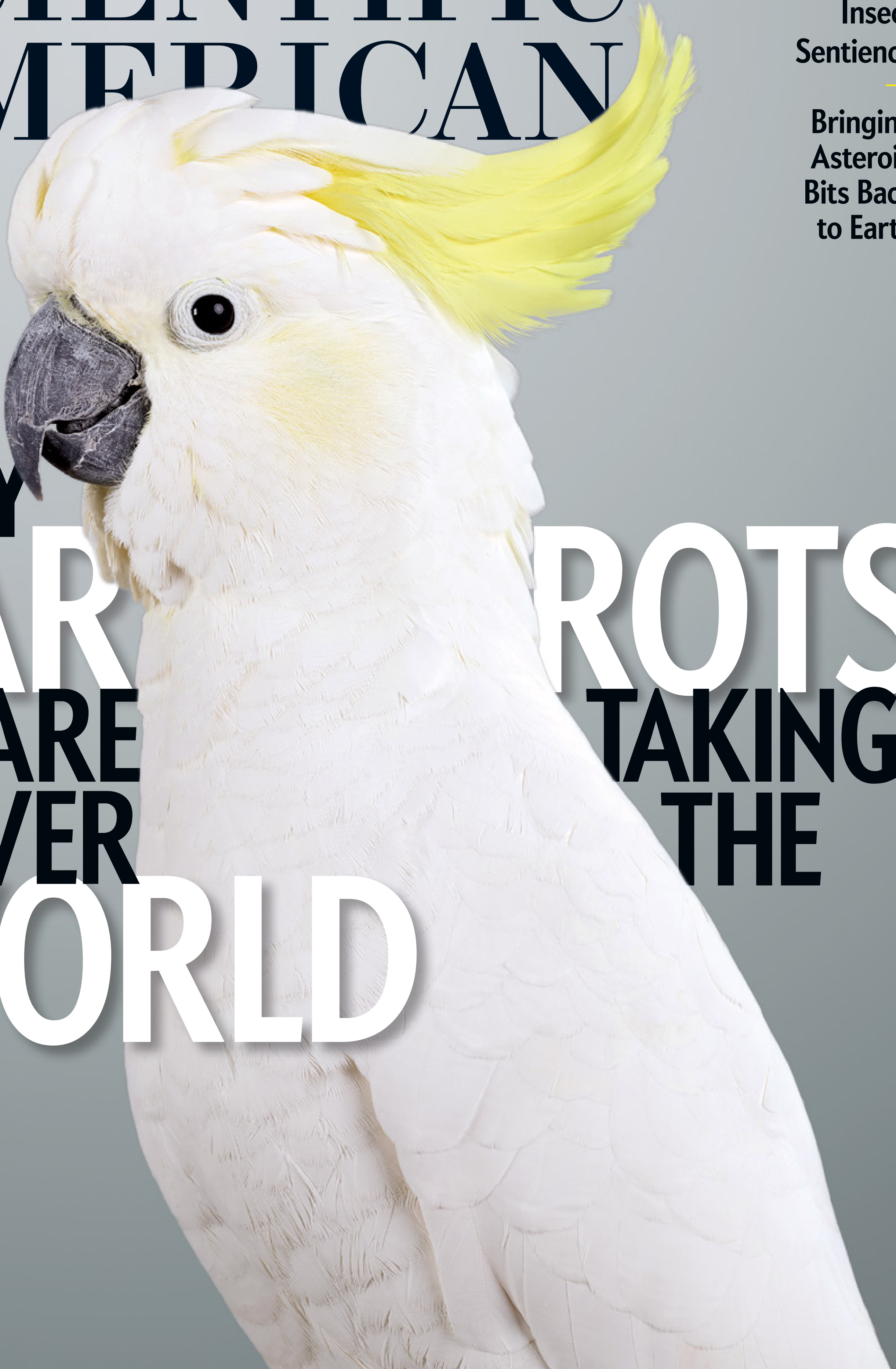
The New Tornado Alley

Insect Sentience

Bringing Asteroid Bits Back to Earth



WHY PARROTS ARE TAKING OVER THE WORLD

ADVANCES

Earth's abundant water makes an impression from space, but its origins are not fully understood.

Samantha Cristoforetti/ESA/NASA

INSIDE

- A bandage sparks healing with electricity
- Mathematical tile conundrum finds a surprising solution
- A full-body experience may make paintings feel like art
- Primates—including humans—love to spin around

PLANETARY SCIENCE

Aqua Earth

Exploring where Earth got its water

In the last hours of the last day of February 2021, a 29-pound chunk of space rock ripped into Earth's upper atmosphere at roughly 8.5 miles per second. As it streaked through the stratosphere, the heat and friction of entry charred its exterior a deep black. Bits of soft rock sloughed off in the blaze, and a huge fireball briefly flared like a torch in the night sky.

By the time the largest piece of debris landed abruptly in a driveway in Winchcombe, England, it weighed only 11.3 ounces. Scientists snagged the rocky, powdery material within 12 hours, making it among the freshest meteorites ever studied. "It's pretty much as pristine as we're going to get," says Ashley King, a planetary scientist at the Natural History Museum in London.

The Winchcombe meteorite belongs to a rare class of space rocks known as carbonaceous chondrites. These volatile bodies are helping researchers piece together one of the biggest puzzles on Earth: where our planet's water came from. Researchers think some may have arrived on meteorites, but how much is hotly debated. Some argue that meteorites made it rain; others say their contribution may have been more like a drop in the bucket.

Before Earth was a planet, it was a cloud of dust orbiting the young sun. Through a process called accretion, this dust condensed to form pebbles that collided and stuck together. The impacts produced increasingly large rocks, which eventually snowballed into a whole planet.

Early Earth was not the "pale blue dot" of today; its temperatures spiked to 3,600 degrees Fahrenheit, more than enough to boil any surface water off into space. Scientists once believed this meant the planet would have been bone-dry in its infancy, but recent research published in *Nature* suggests it might have been significantly wetter. After noting that numerous Earth-like exoplanets were blanketed with a hydrogen-rich atmosphere as they accreted, study co-author Anat Shahar, a geochemist at the Carnegie Institution for Science in Washington, D.C., and her colleagues simulated Earth's formation with such an atmosphere added. They discovered that, contrary to previous hypotheses, lots of water endured in the virtual planet's atmosphere and became encased inside its rocky mantle, even as magma rivers flowed freely across the outer crust.

Although this model suggests that considerable water could have been here since the planet formed, planetary geologists remain confident that a significant portion still came from beyond our atmosphere. "There's so much evidence," Shahar says. "We can't argue against it."

The "smoking gun," King says, is hidden in Earth's hydrogen. Hydrogen exists on Earth in two stable "flavors," called isotopes: regular hydrogen, which has a single proton for its nucleus, and deuterium, whose nucleus is made of one proton and one neutron. Water found in the mantle has about 15 percent less deuterium than seawater; that extra seawater deuterium most likely came from somewhere else.

Astronomers initially theorized that deuterium-rich water traveled to Earth on comets. Because they exist in the solar system's cold outer reaches, comets are extremely icy; up to 80 percent of their mass may be water. But in 2014 data from the European Space Agency's Rosetta mission showed that many comets' isotopic ratio is way off—they have far more deuterium than terrestrial water does. Scientists proposed another hypothesis: water surfed into our atmosphere on the solar wind, which pushes free-range hydrogen and oxygen molecules from space toward Earth. Many scientists maintain, however, that these molecules' deuterium ratio is far too low. "It's hard to explain the water budget from those sources," says Megan E. Newcombe, a petrologist at the University of Maryland.

So where was the Goldilocks isotope ratio? Researchers finally hit the jackpot with asteroids—specifically, raw asteroid chunks called chondrites. Carbonaceous chondrites, which are named for their carbon content, are up to 20 percent water. "This doesn't mean that when you touch the meteorite, it's wet," says Maria Valdes, a geologist at the Field Museum in Chicago. Instead they carry the atomic ingredients for water: a 2:1 hydrogen-to-oxygen ratio.

For a 2022 paper in *Science Advances*, King and his colleagues analyzed the Winchcombe meteorite using spectroscopy. They found that the meteorite's deuterium-

TECH

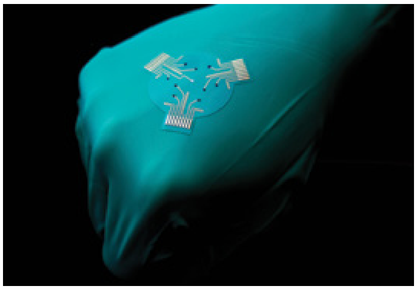
Electric Healing

New bandage zaps and medicates chronic wounds

Some wounds won't heal by themselves. These lesions, which include certain diabetic ulcers, burns and surgical injuries, cause long-term suffering and can linger indefinitely if not successfully treated. They sometimes become infected and in extreme cases turn fatal.

Current chronic wound therapies often require surgery or lead to overuse of antibiotics, which can worsen the problem of antibiotic-resistant bacteria. "Chronic wounds affect tens of millions of people," says California Institute of Technology biomedical engineer Wei Gao. "There's an urgent need for personalized wound treatment."

For a study published in *Science Advances*, Gao and his colleagues used rodents to test a "smart bandage" that could make chronic wound healing easier and faster. It consists of a stretchable polymer patch that adheres to the skin, containing medication and a thin layer of electronics that monitors and wirelessly transmits data about the wound's



condition. The patch can carry out controlled delivery of two treatments: a drug and an electric current.

The bandage builds on previous efforts to promote healing with electricity. This process, called electrotherapy, works both by attracting immune cells and skin cells to the wound and by boosting cell growth and division. A study published last year led by engineer Yuanwen Jiang, now at the University of Pennsylvania, described a bandage that monitored temperature and conductivity, using the collected data to control delivery of electrotherapy.

The new research adds biochemical sensing capabilities. In addition to temperature and pH, the bandage's biosensor monitors levels of ammonium, glucose, lactate and uric acid; together these measurements provide information about inflammation, infection and stage of healing. "Biochemical signals open up new opportunities because you're able to really probe what's happening on a molecular level," Jiang says. "That's the key novelty here." Gao and his colleagues also added an electroactive gel that releases an anti-inflammatory, antimicrobial drug when stimulated by an electrode. Another electrode stimulates the wound directly.

The team tested the bandage on rodents with diabetic wounds and found that it accurately detected changes in inflammatory and metabolic states at different stages of wound healing. The bandage's combined treatments fully healed rodent wounds in two weeks. Each individual treatment achieved at least partial healing within that time, and untreated animals did not heal.

Researchers still need to investigate the bandage's biosensor durability in human patients' chronic wounds. "Requirements for the lifetime of the device are very different between rodents and human subjects," Jiang says. "Stability over that extended period has not been tested yet."

As they head toward human testing, the team is working to improve accuracy and stability. "We hope to apply this smart bandage technology in humans in the next year," Gao says. "Hopefully the information we get can really benefit people with chronic wounds." —*Simon Makin*

California Institute of Technology

to-hydrogen ratio matched Earth's oceans almost perfectly—an especially notable result given how quickly they collected it.

"Meteorites don't like the atmosphere," says Denton Ebel, geology curator at the American Museum of Natural History. The minerals inside space rocks soak up water vapor like a sponge as soon as they hit the air. But because the Winchcombe sample was obtained within 12 hours of impact, it was much less contaminated with terrestrial water than most samples.

A few months after the Winchcombe analysis came out, a study by Newcombe and her team further strengthened carbonaceous chondrites' case. For that paper, published this year in *Nature*, they analyzed several newly fallen meteorites from a group called the achondrites. Unlike carbonaceous chondrites, these meteorites come from asteroids or other rocky bodies that have been partially melted by radiation and geologic processes. Newcombe and her coauthors found that the melting process stripped achondrites of their moisture, like baking cookie dough. "Everything we found, whether it came from the inner or the outer solar system, was really, really dry," she says.

But this discovery doesn't mean carbonaceous chondrites were the planet's only water carriers, notes Laurette Piani, a cosmochemist at the University of Lorraine in France. "In my opinion, there are probably several sources for water on Earth," she says. It would take an awful lot of meteorite impacts to account for the planet's oceans in chondrites alone, and carbonaceous chondrites are fairly rare today. Piani points out that roughly equal parts solar wind, comets, water bubbling up from the mantle and chondrites could be combined to match Earth's isotope balance. Whatever the exact recipe for Earth's water, investigating its origin will reveal more about how our planet formed and became the dynamic blue world we live in. —*Joanna Thompson*

EVOLUTION

Munching Bugs

How insect eating gave early mammals a toothy edge

More than 220 million years ago, as early dinosaurs were just getting their legs under them, the first mammals evolved from a group of tiny, weasel-like reptiles called cynodonts. New research hints that mammals' huge success later on may be linked to a surprisingly small dietary choice: insects.

As cynodonts evolved into early mammals, they developed fewer teeth and skull bones. Paleontologists had long assumed these simplifications allowed for stronger skulls and multiple tooth types, letting mammals benefit from a greater variety of foods. Yet no one knew exactly what drove these changes, and now a study in *Communications Biology* has added a new facet to the story.

"The transition from cynodonts to mammals is a textbook example of repurposing existing skeletal elements," says lead author Stephan Lautenschlager, a paleontologist at the University of Birmingham in England. In their study, Lautenschlager and his colleagues used digital models and biomechanical tests to investigate how the simpler early-mammal skulls held up to biting stresses. Rather than finding increased efficiency or stress resistance in general, they learned that the stress of simulated bites decreased across the top of the skull but increased along the cheek. The specific patterns, and the earliest mammals' relatively small size, are reminiscent of modern small insectivores—which use quick bites and a dental tool kit of puncturing and crushing teeth to bust through arthropod carapaces.

"These findings suggest the patterns we see in the evolution of mammal skulls are more nuanced than we might have thought," says Oxford University Museum of Natural History paleontologist Elsa Panciroli, who was not involved in the new research. "This study gives us fresh data to start getting closer to the answers."

The insect-munching specialists' anatomical changes set the stage for mammal evolution through to today, the researchers say. The changes provided a foundation for later adaptations to feed on plants and larger animals; over time these pioneers became the Mesozoic equivalents of otters, raccoons, flying squirrels and aardvarks. "It's not about how hard you can bite," Panciroli says, "but perhaps about the different ways in which you can bite and chew." —*Riley Black*