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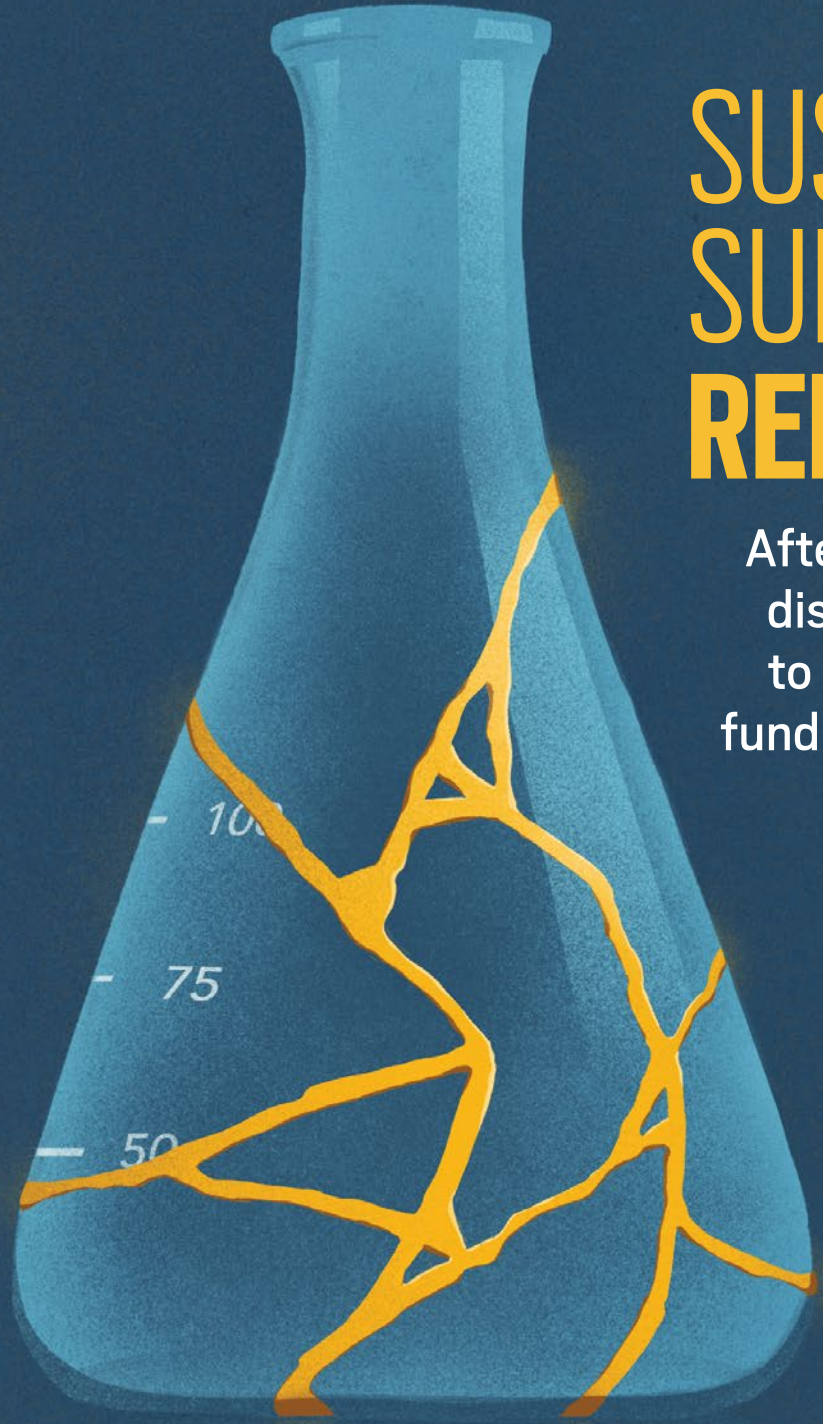

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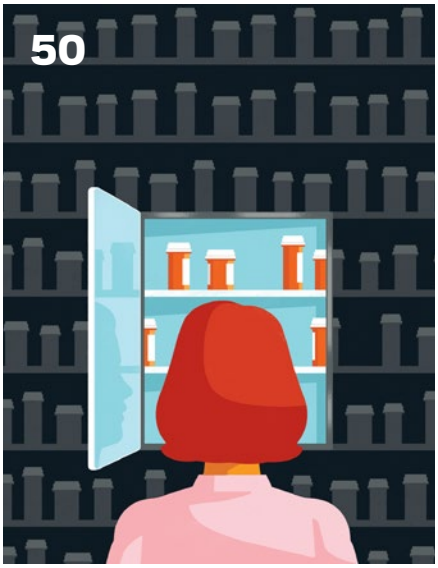

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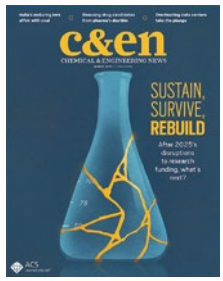

Illustration by Elia Sampò

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Elevating Polymer Chemistry to New Heights

8/18-19 · ACS Fall 2025 at DC Convention Center · CME-STEM.org

8/19 CME Lectures (AM, Ballroom C, featuring Nobel Laureate)
Earth & Space Sustainability (PM, Hall D Room 10)

Moungi Bawendi
Nobel Laureate MIT

Paul Kearns
Argonne NL

James Green
NASA

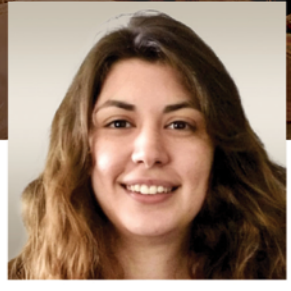
David Bem
PPG

8/18 NASA Day & CME PMSE Session (Hall D Room 10)
ACS Global Student & Mentor Awards in Polymer Science & Engineering

Maggie Horst
Stanford

Yan Xia
Stanford

Hyun-Suk Wang
ETH Zurich



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ETH Zurich

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Change and response

Chemistry has been shaken.

The US government's radical cuts to research funding, the scrutiny on research mobility, and the tariffs on supply lines for industry affect not only those in the US but anyone with connections to the economic superpower. And given that chemical research and engineering account for an estimated 25% of US gross domestic product, the consequences of these changes could be profoundly far reaching.

Our cover story explores these changes and the hope for building a more resilient chemistry enterprise from the disruption. After all, the disruption to German industry in the aftermath of World War I proved to be an inflection point for shaping future research funding in the UK. The British sent a delegation to Germany looking for inspiration and realized a thriving research sector is based on more than a physical plant.

▲ **Scientists work in a laboratory in British-occupied Bonn, Germany, in 1919.**

There is a similar sense of opportunity and concern in Europe at the moment. Scientists across the continent recognize the outsized impact of US science and the dependency that that impact has bred. The European Research Council, taking a cue from member states like France and Germany, has pledged to double its budget and invest in strategies to attract US researchers. This sense of urgency is reflected in other global regions.

Acknowledging our audience's preferences

The cover is timely for what's next for chemistry, but it is also prescient for C&EN.

Changes in science journalism and how people consume it have been evolving for more than the 7 months of the second Donald J. Trump administration. Nonetheless the consequence of technological change is having a profound and far-reaching impact on media. And it feels dizzyingly fast too.

We are no longer in a world where C&EN can assume that our entire audience reads the print magazine. There are too many options to get your news and information, whether it's in an email or an endless scroll on your phone. We need to be more thoughtful about why readers prefer one channel of delivery over another.

We have focused heavily on researching who prefers the print magazine and why. So in our new print redesign, which launches with this issue, we are extending space for long-format journalism, so that readers can really explore a topic. We hope our story selection maintains that feeling of discovery that comes with turning a physical page, something we know some readers prefer over the recommendation engines online that curate your reading lists based on what you last read.

We have also made this a more pleasant reading experience with more space, larger fonts, and more dynamic use of images and graphics. The digital version will soon be available as a two-page spread, mimicking the experience of reading a physical magazine. In short, our magazine should feel like a substantive treat for our readers.

As I have noted before, our move to a monthly edition supports this enhanced print product while boosting content on various digital platforms.

Not all change is the same

Unlike many of the announcements in US federal policy, our changes here at C&EN are not driven by cuts to funding. American Chemical Society, as a publisher, has been steadfast in its commitment to supporting a vital and independent journalistic product. Our investment in an upgraded website and growing our coverage internationally, for instance, are a reflection of the trust our publisher places in our value proposition.

What this period of disruption does prove, though, is that there is value in reflecting on the assumptions we are making in our work and about our future. Navigating uncertainty and shifts in our assumptions is familiar to anyone working in a laboratory. But it is more challenging when it comes to policies, institutions, or people, where questions of consequence face uncontrolled dynamics.

But when the world around you is changing, the worst thing you can do is nothing. Make a decision. And learn from it.—**Nick Ishmael-Perkins**

Views expressed are not necessarily those of ACS.

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We've reimagined our digital experience for clarity, sharing, and deeper exploration

Improved Search Functionality
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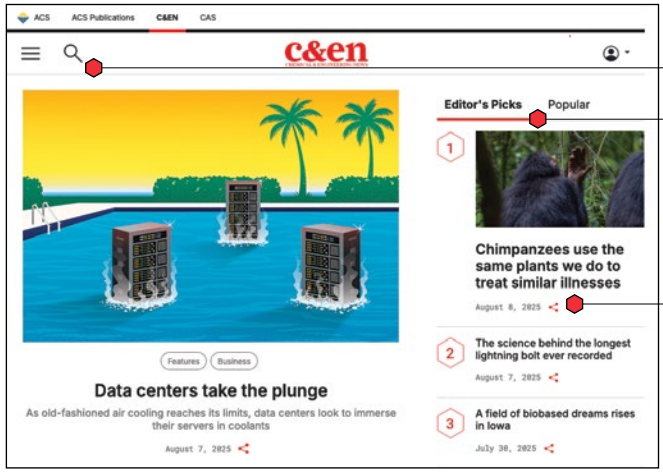
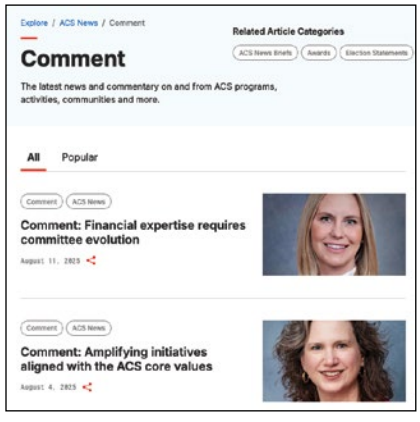
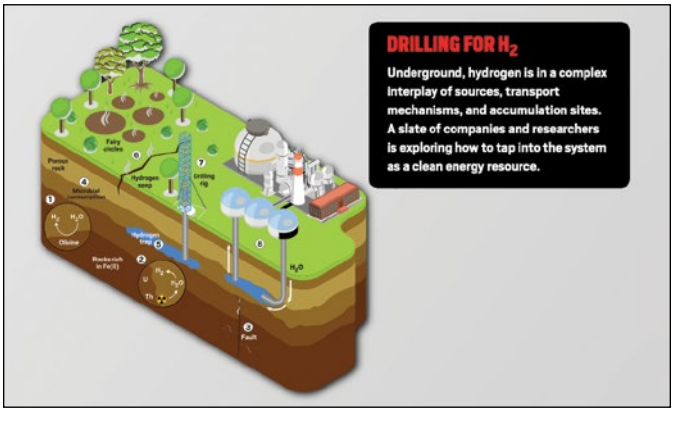


◀ Improved Navigation
Our refined site menu helps you find content faster.



▲ Expanded ACS Comment Section
Read about what's happening in the larger ACS community.



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Career Tips for Advanced Professionals ▶ Content now includes advice and opportunities tailored for seasoned professionals.

BEYOND THE WEBSITE AND PRINT MAGAZINE

The redesigned website and print magazine are just the beginning. C&EN has also launched several new editorial initiatives to enhance your experience:

◀ Future of Chemistry and New York City Live Events: Insightful panel discussions on emerging challenges and opportunities across the chemical sciences.

▲ *Inflection Point* Podcast: This narrative podcast explores the pivotal historical moments behind the science everyone is talking about.

▶ What's Next: New Products and Personalized Features

To keep you informed and deepen your engagement with chemistry, C&EN's editorial team is developing a suite of new offerings, such as:

- New topical newsletters
- A more personalized mobile app experience
- More columns by thought-leading guests
- A new suite of chemistry-themed games

Save the Chemical Safety Board

In response to the C&EN article "White House Moves to Kill Chemical Safety Board, Despite Industry Support," I urge Congress to reject efforts to eliminate the US Chemical Safety and Hazard Investigation Board (CSB). Without the CSB, we risk more disasters and less accountability for workers and communities in harm's way.

After repeated chemical catastrophes, Congress saw the need for serious, independent investigation—not regulation—for industry-wide learning. The CSB's impartial reports and detailed safety videos have become trusted tools for labor unions, chemical engineers, public health experts, and the chemical industry itself, all of which want it to continue because they rely on its recommendations to improve safety.

The value of the CSB is clear: about 177 million people in the US could potentially be affected by chemical catastrophes' worst-case scenarios, according to a 2016 US Environmental Protection Agency report. And nearly 1 in 10 US schoolchildren goes to school within a mile (1.6 km) of a hazardous chemical facility, according to the Center for Effective Government. Incidents from the past several years—including the train derailment in East Palestine, Ohio, and the Intercontinental Terminals Company fire in Deer Park, Texas—show that chemical accidents are not rare or trivial. The CSB's annual budget, just $14 million, is minuscule versus the cost of around $2.7 billion for damages and personal suffering in 2016–20, according to a 2024 analysis by the EPA.

Without the CSB, we lose root-cause analysis that helps prevent accidents. The Occupational Safety and Health Administration and the EPA do critical work, but neither is set up to conduct this kind of independent accident research or issue forward-looking safety guidance. The CSB fills a dangerous gap, one only growing as deregulation, aging infrastructure, and climate change threaten more communities.

Over its 25-plus years, the CSB has sent investigators to over 170 chemical incidents, helping uncover failed safety systems and drive real change. By providing clear technical recommendations, it has influenced how companies and regulators approach hazardous processes. That's why industry and the public broadly support its work, even as the White House claims it duplicates other agencies.

Congress has wisely rejected past proposals to shutter the CSB. With chemical accidents occurring every few days and the stakes for workers and neighbors rising, now is not the time to eliminate our nation's only independent chemical accident board. Keep the CSB funded and working for all Americans.

Vedaansh Uberoi
Durham, North Carolina

Too much hype on sodium fuel cells?

I am writing to express my disappointment in C&EN's credulous coverage of a sodium fuel cell that could be used to power an airplane in the June 9 issue (page 6). I am not disputing that the disclosed fuel cell system appears to be an advance in fuel cell technology. However, the idea that a commercially viable plane could be powered by a liquid sodium fuel cell stretches the imagination, and C&EN's reporting of this claim at face value discredits the publication.

While a nonchemist cannot be expected to know of elemental sodium's myriad dangers, a writer for C&EN should be well aware of them. Even a cursory examination of this idea reveals multiple significant problems, such as How would you safely fuel a plane with liquid sodium on a tarmac exposed to the elements? How would an airport safely store and heat the thousands of gallons of sodium needed to fuel these planes? What would happen if one of these planes crashed, especially into a body of water? Finally, how would one of these planes compete with current jet-powered planes

when the theoretical range is less than a 10th of a current comparatively sized plane? Even the idea that the by-product "NaOH could be ejected into the atmosphere to react with CO_2 and form sodium carbonate" is questionable. Air travel is unpleasant enough without the airport and surrounding area being regularly misted with a fine spray of lye.

Although it may seem like I am being overly critical of an idea that will never be commercialized, I think it is very important that publications like C&EN publish all their articles with rigorously researched neutrality. There have been far too many instances over the years in which poorly thought-out ideas are positively reported on purely because they are "green." This inevitably results in disappointment and disillusionment from the general public when they either fail or peter out, and it contributes to public distrust of science. I hope C&EN will employ a more skeptical attitude when reporting on advances like this in the future.

Matt Porter
Cleveland

Lack of incentives to publish in industry

The interesting article "Why Don't Medicinal Chemists from Industry Publish Anymore" by Dalmeet Singh Chawla (C&EN, June 16/23, 2025, page 25) brought to mind a comment from a previous research supervisor: "Right now, nobody's career in this company is being helped by submitting requests to approve the release of information." What's missing from the article is any discussion of how to establish a business case for allowing an employee to publish results from work done for the employer. From the company's perspective, it is easy to see how publication or presentation could be considered an activity that presents costs and risks to the employer but only has vaguely defined business benefits. Publishing or presenting is not free to the company; it consumes the time of authors, supervisors, and company legal departments. Unless a prospective author can make a case that these costs are outweighed by tangible benefits, it is difficult to obtain approval to publish or present.

Joseph P. Smith
Creve Coeur, Missouri

Serve as a panelist or reviewer for the NSF

I recently completed an assignment with the US National Science Foundation (NSF) as a visiting program officer ("rotator") in the Division of Chemistry. In my time at the NSF, I was impressed by the empathy and support shown by principal investigators and panelists toward NSF staff—particularly given the heightened challenges of the past 6 months. Your understanding has been deeply appreciated.

As many of you know, the NSF is currently experiencing a period of significant transition. Staff reductions due to firings, retirements, and participation in the deferred resignation program (DRP, or "fork"), combined with an ongoing hiring freeze, travel pause, and other measures, have all resulted in fewer program officers available to carry out the NSF's mission. Looking ahead, there is the likelihood of further disruptions, such as the recently announced relocation of the NSF from its mission-designed headquarters building and a proposed agency reorganization that could introduce additional uncertainties and challenges.

Given these circumstances, I urge all community members to thoughtfully consider invitations to review proposals or serve on panels. Even in ordinary times, identifying qualified reviewers is a challenge. Declining such requests—especially because of concerns about the NSF's current or future state (factors outside program officers' control)—can inadvertently increase the workload on already-stretched program officers and may negatively impact the review process of proposals submitted by your colleagues.

Now, more than ever, the NSF depends on the collective commitment and expertise of our community to maintain the rigor and fairness of the peer review process. If you are able, I encourage you to accept invitations to serve as a reviewer or panelist. Your participation truly makes a difference.

John Protasiewicz
Cleveland, Ohio

CORRECTION

July 28, 2025, page 15: The feature article about per- and polyfluoroalkyl substances in biosolids incorrectly names John Follin the director of demilitarization and chemical waste destruction at General Atomics Electromagnetic Systems. He is director of strategic development for industrial supercritical water oxidation technologies.

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Publishing | Story of the month

Controversial ‘arsenic life’ paper retracted

The journal cites experimental error as the reason for the decision, which comes nearly 15 years after the paper’s publication

After almost 15 years, the influential scholarly journal *Science* has retracted a controversial paper about the discovery of a microbe able to use arsenic instead of phosphorous in its biochemical processes (*Science* 2010, DOI: 10.1126/science.1197258).

In the retraction notice, H. Holden Thorp, *Science*’s editor in chief since 2019, states that the paper is being retracted on the basis that the “reported experiments do not support its key conclusions” but not because of any deliberate fraud or misconduct.

The retraction is accompanied by a letter from the authors disagreeing with the decision, stating, “While our work could have been written and discussed more carefully, we stand by the data as reported.”

In the original paper, the authors describe an extremophile microbe called GFAJ-1 that they believe has the ability to weave arsenic into its proteins and nucleic acids to compensate for a lack of phosphorus. Confirming that arsenic can be incorporated into DNA has the potential to expand the chemical understanding of life on Earth—and beyond, an aspect that NASA and the journal initially played up.

▲ **The “arsenic life” microbe came from Mono Lake, a highly alkaline, arsenic-rich body of water in California.**

The paper immediately garnered harsh criticism from the scientific community over the researchers’ methods and conclusions. In 2012, *Science* published two papers from independent teams who were unable to replicate the original paper’s results.

The current consensus is that although GFAJ-1 is unusually good at growing in high concentrations of toxic arsenic, sufficient evidence hasn’t been found that it actually incorporates arsenic into its DNA, and the bacterium likely survives by scavenging trace phosphorus from its surroundings. The authors say in their letter that these follow-ups didn’t adequately reproduce their original growth conditions for GFAJ-1.

Back in 2012, *Science*’s policy was to retract papers only in cases of misconduct, which this is not.

CREDIT: AL UNGAR/SHUTTERSTOCK

But, Thorp says, "The expectations for straightening out the literature have risen significantly," and calls for the paper to be retracted have simmered throughout his tenure at the journal.

The tipping point was a *New York Times* profile of Felisa Wolfe-Simon, the paper's outspoken first author, that was published in February 2025. Thorp went on the record in that article saying he thought the paper should be retracted.

According to guidelines from the Committee on Publication Ethics (COPE), "Retraction is a mechanism for correcting the literature and alerting readers to articles that contain such seriously flawed or erroneous content or data that their findings and conclusions cannot be relied upon. Unreliable content or data may result from honest error, naïve mistakes, or research misconduct."

Science's current retraction policy states, "An accumulation of errors identified in a paper may cause the editors to lose confidence in the integrity of the data presentation, and the paper may be retracted."

Ariel Anbar of Arizona State University, one of the original paper's authors, says the uncertainty in the data is "larger than one would like," but "we don't think there was a major error" that warrants retraction.

Anbar says Thorp asked Wolfe-Simon to voluntarily retract the paper last fall, after he was contacted by the *New York Times*. She refused. After months of negotiations, the researchers and journal editors reached a compromise: The paper would be retracted with language that both parties agreed on. The researchers could voice their dissent in a letter.

In addition to posting the retraction notice, Thorp and *Science*'s executive editor, Valda Vinson, published a blog post in which they expand on their reasons for retracting the paper. In the post, they reiterate that the decision is rooted in experimental error and "at no point has there been any discussion or suggestion at *Science* of research misconduct or fraud by any of the authors."

Thorp says he hopes that retracting the paper will put a period on the whole affair. "I hope this is the end of it," he says.

Anbar says he and his coauthors asked to see the blog post ahead of time, and the journal didn't respond; they received a copy from a reporter. The post brings up critiques beyond what went into the notice, which Anbar says undermines the good-faith commitment to transparency that the authors and editors made when negotiating the retraction.

One thing both Anbar and Thorp appear to agree on—although for different reasons—is wishing that arsenic life hadn't whipped up such a firestorm in the first place.—**Brianna Barbu**

CREDIT: TOMMY WACHSMUTH/C&EN

Molecular Machines

This machine is designed to wind

Light- and heat-powered motor twists catenanes into being

▲ **This conceptual version of the catenane made by Michael Kathan and coworkers shows the molecular motor portion of the molecule on the left.**

Think of it as a way to make molecular chain mail: a new molecular machine that winds two molecular threads together to make mechanically interlocked molecules known as catenanes. Catenanes feature macrocyclic loops held together like links in a chain. To break the chain requires breaking a covalent bond. Although chemists have been making catenanes for decades—their discovery garnered the 2016 Nobel Prize in Chemistry—they usually use complex templating strategies. This molecular machine instead twists two molecular threads together using light and heat (*Science* 2025, DOI: 10.1126/science.adx5363).

The molecular machine was designed by chemists in Michael Kathan's lab at Humboldt University of Berlin. Kathan says the idea of making such a machine came to him when he was a graduate student studying switchable molecules. "The question was, What can we do with molecular machines that you cannot do otherwise?" he says.

The core of the catenane-making machine is a molecular motor that →

makes a unidirectional 180° turn when exposed, alternatingly, to light and heat. Each half-circle turn creates a crossing between the molecular threads. Two crossings entwine the molecule so that it can form a catenane, and once the motor has made a full circle, the chemists covalently link the threads together and then chemically snip a link to the motor, releasing the catenane.

The motor's synthesis isn't mentioned in the paper and instead takes up 25 pages of the supplemental information published alongside. Kathan says it was a daunting task. "My coworkers spent most of their time synthesizing these machines," he says. "It's always a bummer if the thing you just scribbled on a piece of paper doesn't work out, and then you invest weeks or months in synthesis and try to figure out how you could make it work experimentally."

Kathan says his team's approach to making mechanically interlocked molecules isn't limited to catenanes but could also be used to create molecular knots and rotaxanes. "The method of making these molecules is always the same: You introduce a certain number of crossings in a molecular strand, and then you try to covalently capture them in an appropriate manner," he says. The molecular machine developed in his lab can introduce a defined number of crossing points in any molecular strand; the strand just needs to be sufficiently long and flexible.

David A. Leigh, who makes mechanically interlocked molecules at the University of Manchester, agrees that making different torus knots and links with this machine could be possible if you can get the motor to make more than one complete turn—something Kathan's lab was able to do, although they were unable to make the necessary covalent link between the threads to secure the shape.

Leigh notes that light-driven motors might be tricky to use though, because they become increasingly unstable with more strain. "But challenges are there to be overcome," Leigh says in an email. "It's a wonderful demonstration of how molecular motors can be used for mechanically manipulating molecular units for synthesis."

Ivan Aprahamian, a chemist at Dartmouth College who specializes in molecular switches, says in an email that the work "will inspire the design of molecular machines that can pick up reactive threads from the solution, interlock them through their motion, and then release them to the environment." That's a goal Kathan says his lab is working toward.—**Bethany Halford**

Persistent Pollutants

Modified MOF senses and removes PFAS

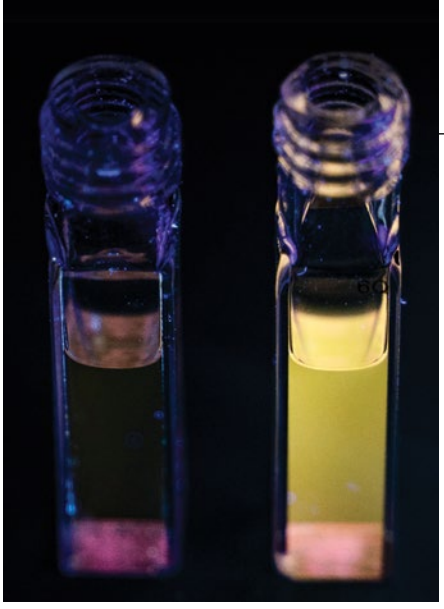
Material glows when it captures perfluorooctanoic acid

With a few chemical tweaks to a known metal-organic framework (MOF), researchers have developed a material that quickly detects and removes a common per- and polyfluoroalkyl substance (PFAS) from contaminated water (*J. Mater. Chem. C* 2025, DOI: 10.1039/D5TC01765C).

PFAS are chemicals that persist in the environment and that can be toxic at low levels. Researchers in academia and industry are racing to develop PFAS sensors as well as methods to remove or destroy these so-called forever chemicals.

The new MOF glows under ultraviolet light when it detects the common PFAS perfluorooctanoic acid (PFOA), and it captures 99% of PFOA from 50 parts per billion (ppb) aqueous solutions within minutes. "Multifunctional materials like this one can be key to optimizing PFAS treatment technologies by streamlining detection and removal into a single, efficient platform," says Mario Wriedt, a chemist at the University of Texas at Dallas who was not involved in the work.

MOFs contain metal nodes linked by organic ligands to create 3D interconnected channels, which make them excellent at capturing PFAS, says Ling Zang, a materials scientist and engineer at the University of Utah. Another thing going



An aqueous solution of a new metal-organic framework (MOF) usually appears colorless under black light (left). But when perfluorooctanoic acid (PFOA) is present, the MOF captures the PFOA and glows yellow.

CREDIT: RANA DALAPATI

for MOFs is that the ligands are easy to modify, he says.

To make the new material, Zang and his colleagues started with a zirconium-based MOF known as UiO-66-NH_2. That MOF has been studied extensively for applications in water purification and carbon capture. They treated it with methyl iodide, which turns the neutral amino groups on the MOF ligands into positively charged ammonium ions. Then the researchers loaded the MOFs with a commercially available dye that is negatively charged and electrostatically sticks to the ammonium groups in the MOFs. They tested the MOFs on aqueous PFOA solutions with concentrations as high as 1,000 parts per million and as low as 50 ppb.

"When the dye is captured inside the MOF, it is dark," Zang says. But PFOA molecules, which bind more strongly with the MOF, nudge the dye molecules out of their spots. The dye's fluorescence turns on once it's released, indicating the presence of PFOA.

Each gram of the MOF soaks up about 1,000 mg of PFOA, an adsorption capacity much higher than that of many other MOFs and twice that of activated carbon, the established material for PFOA removal, he adds. By tuning the ligands of the MOF to alter its chemistry as well as the geometry and size of the voids, "we aim to expand the target PFAS to cover at least the top six PFAS found in drinking water, as classified by the EPA [US Environmental Protection Agency]," Zang says.

Although this is an important advance, Wriedt says, the material's detection limit of about 90 ppb is about four orders of magnitude higher than the EPA's limit of 4 parts per trillion for PFOA. The researchers also need to validate the MOF's performance in more-complex field samples, "where competing ions and organic matter may affect both adsorption and sensing."

The industry is moving toward short-chain PFAS, which are more persistent and mobile, says Soumya Mukherjee, a chemist at the University of Limerick who also was not involved in the work. Electrostatic forces are relatively weak, making short-chain PFAS more difficult to remove using adsorbents. "The combination of multiple forces [such as hydrophobic and electrostatic] is a potential research direction for the removal of short-chain compounds in the future."—**Prachi Patel**

Biomaterials

AI-designed superglue retains extreme strength under water

Glue instantly stopped water gushing from a 2-cm hole in a pipe

Extremely sticky, waterproof glues have long been a critical necessity of mankind. Now, researchers have developed two such superglues that were designed by artificial intelligence after taking inspiration from a plethora of sticky proteins found in nature (*Nature* 2025, DOI: 10.1038/s41586-025-09269-4).

One of the holy grails of materials science has been concocting strong and reliable waterproof glues, a quest that's notoriously dependent upon trial and error, thus making the process luck based. Traditional glues often fail in wet environments because water disrupts the critical interactions needed for adhesion. Yet, nature is replete with organisms such as mussels, barnacles, and other marine creatures that have evolved to adhere strongly in wet, even turbulent conditions.

Hailong Fan of Hokkaido University, Japan, and his team mined a comprehensive dataset of over 24,000 adhesive proteins from bacteria, eukaryotes, archaea, and viruses, spanning over 3,800 species. "Rather than mimicking one organism like the mussel, we essentially let evolution be our guide, treating nature as a massive design database," Fan says.

They found that despite their taxonomical diversity, these proteins shared characteristic amino acid sequences, especially the pairwise arrangements of amino acid functional classes

involved in adhesion. Next, they created 180 novel, waterproof glues from random, free-radical copolymerization of six monomers, each representative of an amino acid functional class.

Then the team measured the underwater strength of every glue, with an *Escherichia* derived glue emerging strongest at 147 kilopascal. Mussels, by comparison, can latch onto rocks with roughly 800 kPa of force. The researchers used this data to train machine learning models to conjure novel, better performing designs and predict their underwater strengths. Next, the team synthesized glues predicted to have topnotch strengths, measured their actual strengths, and then again fed this data to the ML models. Ultimately, they ended up with three sample glues (named R1-max, R2-max and R3-max), each being the top-performer of its respective "learning" round.

They found that the glues exhibit mind-boggling underwater strength with R1-max topping the chart at more than 1 million Pa. More than 200 cycles of attachment and detachment failed to weaken R1's grip, and it held together plates of various materials under a 1 kg load for more than a year, demonstrating its reusability and longevity. A rubber duck that was attached to a seaside rock with R1-max withstood relentless crashes of ocean waves and tides, a testament to its exceptional durability. And R2-max instantly sealed a 2-cm-diameter hole at the base of a three-meter pipe filled with tap water.

Robert Macfarlane, a materials scientist at the Massachusetts Institute of Technology who wasn't involved in the study, describes the work as mimicking "a biological evolution process that optimized material design for a specific performance." He calls it "an interesting example" of using machine learning and data mining to produce functional materials.

▲ A superglue discovered by AI analysis kept this rubber duck firmly affixed to a rock in a coastal area even as ocean waves repeatedly crashed down on it.

CREDIT: HAO GUO, HONGGUANG LIAO, AND HAILONG FAN

Using commercially available monomers and simple free-radical polymerization makes this approach scalable, Macfarlane says. He adds that "processing the materials into useful and application-ready form factors, and other issues, including the long-term stability and toxicity of the materials, and the response of these materials to different environments" would have to be addressed before its widespread adoption.—**Soumya Sagar, special to C&EN**

CREDIT: PATRICK PLEUL/PICTURE-ALLIANCE/DPA/AP IMAGES

Atmospheric Chemistry

The science behind the longest lightning bolt

What atmospheric conditions lead to lightning megaflashes?

For 7.391 s in the wee hours of Oct. 22, 2017, a "megaflash" of lightning lit up 515 miles (829 km) of sky from Fort Worth, Texas, to Kansas City, Missouri, in a single brilliant stroke.

Analysis of satellite data with new computational techniques has shown that the megaflash, which connected with 116 places on the ground, is currently the longest on record (*Bull. Am. Meteorol. Soc.* 2025, DOI: 10.1175/BAMS-D-25-0037.1). The previous record was a 2020 megaflash that spanned 477 miles (768 km) from Texas to Louisiana.

But the factors that cause such megaflashes, which are defined as lightning that has traveled more than 100 km, are still unclear. In fact, "why lightning happens has been a mystery for the longest time," Michael Peterson of the Georgia Institute of Technology, who led the satellite data analysis, told C&EN in an email.

At its core, lightning occurs when opposing electrical charges build up in the skies and then recombine, either through lightning bolts in the clouds or strikes to the ground, as Benjamin Franklin demonstrated almost 300 years ago by flying a kite in a thunderstorm.

Charge separation can occur when atmospheric particles collide in a brewing thunderstorm. For instance, small ice particles can lose electrons to larger soft hail pellets and then get carried upward quickly, leaving the heavier hail pellets behind, Peterson says.

But to make a megaflash, electrical charges need to separate steadily for miles and miles without recombining. "If there was a recent prior flash, then there might not be sufficient charge to allow for continued horizontal expansion, and the flash never reaches the megaflash scale," Peterson explains.

Stratiform clouds, one of many types of clouds, can provide an ideal environment for the formation of megaflashes, Peterson says. These are flat, blanket-like sheets of cloud that stretch long distances across the skies, an ideal conduit for distributing the positively charged light ice particles.

In July, researchers led by Victor Pasko of Pennsylvania State University reported that lightning could be initiated because of runaway atmospheric chain reactions in thunderstorms (*J. Geophys. Res.: Atmos.* 2025, DOI: 10.1029/2025JD043897). Their findings suggest that strong electric fields created in a thunderstorm environment accelerate electrons, causing them to slam into atmospheric gases such as nitrogen and oxygen with enough energy to produce X-rays. The X-rays, in turn, generate more electrons and high-energy photons, which ultimately trigger lightning.

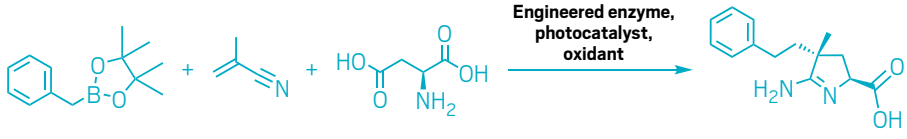
While those findings are relevant for explaining the overall initiation of a megaflash, they still don't explain how charge separates over large areas or where a bolt from a megaflash could strike the ground, Peterson says. Many factors for creating the conditions to support a megaflash still need to be investigated. That would help researchers understand how megaflashes build and also help predict where they could strike along the many miles they span, all of which can help manage lightning-triggered disasters such as wildfires.—**XiaoZhi Lim, special to C&EN**

▲ **Sometimes lightning bolts can stretch hundreds of miles horizontally. A new study reveals the conditions that underpin these megaflashes.**

Biocatalysis

Modular reaction can build hundreds of unnatural amino acids

3-component reaction mediated by enzyme and photocatalyst does mix-and-match chemistry



Researchers at the University of California, Santa Barbara, unveiled a new modular way to combine three mix-and-matchable molecular pieces into new amino acid derivatives using an engineered enzyme and an organic photocatalyst (*Science* 2025, DOI: 10.1126/science.adx2935).

This isn't the first three-component reaction to use an enzyme, but it is notable for providing easy access to new chemical space for unnatural amino acids that could potentially be valuable in medicinal chemistry. "We can have very diverse products," says Yang Yang, who led the work.

The new work builds upon Yang's previous work orchestrating two-component reactions using engineered pyridoxal phosphate (PLP)–dependent enzymes in tandem with a photocatalyst to stereoselectively modify amino acids.

This expanded version of the reaction brings together a boronate radical source, an unsaturated carbonyl or nitrile radical acceptor, and an amino acid (the researchers used mainly aspartic acid). It can generate six possible product types, most of them cyclic, depending on the structure of the radical acceptor piece and the reaction conditions.

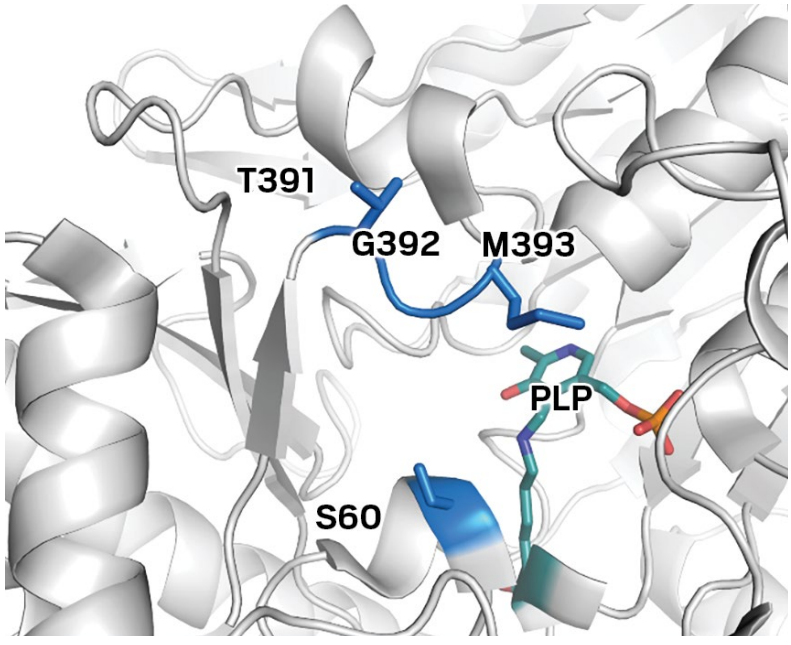
The researchers demonstrated their method's powers of stereochemical discernment with several experiments. For example, when they started with a mixture of four β-methyl aspartic acid stereoisomers, only one successfully underwent a reaction. They also used the reaction in what's called a parallel kinetic resolution, in which each stereoisomer of a key intermediate makes a different product.

To test the method's combinatorial potential, the researchers mixed and matched 10 boronates with 10 carbonyls and nitriles, half of which hadn't been tried in initial studies of the reaction scope. They found that all but one of the 100 possible combinations showed some degree of reactivity with at least one of the four enzymes they tried. "This level of synthetic versatility is fairly rare in enzymatic reactions," Yang says.

▲ A new method for constructing unnatural amino acids from three modular pieces combines radical bond formation with enzymes' knack for stereoselectivity.

Biocatalysis researcher Xiongyi Huang of Johns Hopkins University, who was not involved in the work, says it "opens access to a whole new chemical space for nonnatural amino acids." Robert Phillips of the University of Georgia, a specialist in PLP-dependent enzymes, says it is a "brilliant extension of [Yang's] previous work."

Yang and coworkers have filed a patent for the reaction. He says they are in talks with a couple of pharmaceutical companies about collaborating to use their enzymes for drug discovery. Meanwhile, the team is continuing to work on devising new complexity-generating biocatalytic reactions.—**Brianna Barbu**



▲ Yang Yang's engineered enzymes rely on pyridoxal phosphate (PLP) as a key component of the biocatalysis cycle.

CREDIT: QORE

Biobased Chemicals | Story of the month

A field of biobased dreams in Iowa

Does a new butanediol plant that runs on corn represent a shift in how chemicals are made?

Towering above the dark green fields of Iowa, a new $360 million factory is challenging the premise that the spandex raw material 1,4-butanediol must be made from fossil fuels.

Over a period of about 50 years, companies built plants that make butanediol, which also goes into polyurethanes and many other products, via at least five different synthetic routes. All of them start with coal, oil, or natural gas as their raw material. The Iowa facility starts with dextrose derived from corn.

The plant is a joint venture between the agribusiness giant Cargill and the chemical trader Helm. Built at a large Cargill corn-processing complex in Eddyville, it uses genetically modified bacteria to ferment dextrose into as much as 66,000 metric tons (t) of butanediol per year. It is the largest single US investment in biobased chemicals in about 20 years.

The venture, called Qore, held a grand opening July 22 under the hot Iowa sun, the kind of day on which farmers say they can hear the corn growing. By getting off the ground, Qore is breaking a string of failed attempts to produce chemicals from agriculture instead of from fossil feedstocks. Still to be determined is whether Qore is a sign of renewal in the business of making chemicals with biology or just an isolated success.

▲ **Qore makes 1,4-butanediol in its new plant from corn grown in nearby fields.**

The event was held in an air-conditioned tent a stone's throw from the new facility. As speakers toasted the accomplishment, steam was already puffing around the distillation columns. Behind the columns, large fermentation tanks sat in a tall climate-controlled building. Underground pipelines were poised to move the product from three outdoor storage tanks to railcars ready to carry shipments to customers.

One of those customers is Lycra, the spandex maker. Lycra CEO Gary Smith said at the event that Qore is scheduled to send 2,000 t of butanediol next month to Dairen Chemical, a Taiwanese company that will turn the intermediate into poly(tetramethylene ether glycol), the main raw material for spandex, which Lycra will produce in Singapore. Textile companies will then weave the fiber into a fabric and sew it into athleisure wear and other garments.

Smith is betting that brand name customers like Lululemon Athletica and Spanx will be willing to pay for a more sustainable fiber made with a biobased chemical. Lycra calculates that its spandex will have a carbon footprint up to

44% less than that of fossil-based products.

Qore CEO Jon Veldhouse likewise acknowledged that Qore is looking for customers that want a product with a good environmental profile, not the lowest price.

Customers seem to be interested. In addition to Lycra, the big chemical maker BASF has signed a contract to buy some of Qore's output. BASF is already a large maker of fossil-based butanediol, which it turns into products such as polyurethanes and the engineering polymer polybutylene terephthalate.

Veldhouse said Qore's shareholders, Cargill and Helm, want to grow their venture, possibly through a second plant in the coming years. "For us, the future is quite clear," he said. "Our shareholders have balance sheets to invest in this business."

Growth in large-volume biobased chemicals and fuels has not come easily. Multiple companies started producing biobased succinic acid about a decade ago, only to later shut down when demand didn't materialize. Start-ups like Amyris, BioAmber, LS9, and Zymergen either went out of business or were acquired on the cheap. Biobased chemicals like lactic acid and 1,3-propanediol have taken hold but not exactly flourished.

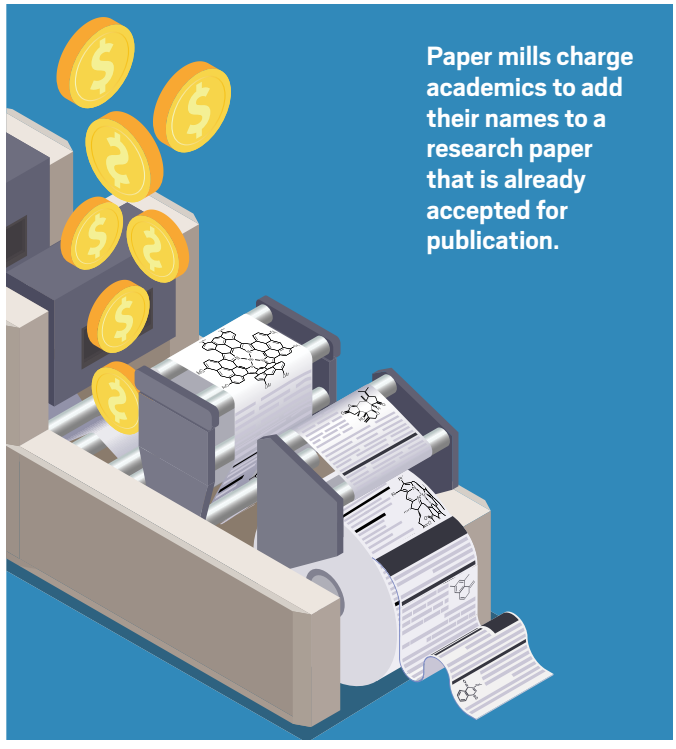
But Steve Slome, an analyst with the consulting firm NexantECA who helped prepare a recent technoeconomic report on biobased butanediol, says butanediol has unique attributes that position it for success.

Butanediol is "an exceptionally good biochemical target," he says. The genetic modification required to get *E. coli* to convert dextrose into butanediol via succinyl-coenzyme A is straightforward, Slome says. "The biology is nice and simple."

And the fashion and garment industries value the brand halo that a sustainable product can bring—and they often have the profit margins to pay for it. "A company like Patagonia, if they were using spandex or Lycra, this would be the spandex they'd use," Slome says.

At the Iowa event, Veldhouse said consumers are changing as well. It started with people interrogating what they eat or apply to their bodies and asking for materials that are more responsibly sourced. "The natural extension to that are consumer products that you put on yourself, and you're making an informed decision about that," he said. "We are answering the call for more responsibly sourced materials."

Looming in the background on that hot Iowa day was the $360 million bet that Cargill and Helm are placing on what they think consumers want.—**Michael McCoy**



Paper mills charge academics to add their names to a research paper that is already accepted for publication.

CREDIT: YANG H. KU/C&EN/SHUTTERSTOCK

Publishing

Brokers of scientific fraud growing rapidly, study finds

Publishers are not keeping up with paper mills and other purveyors of shoddy academic papers

Companies that broker and facilitate scientific fraud are large, resilient, and growing rapidly, according to a new study.

The analysis, published in the *Proceedings of the National Academy of Sciences of the United States of America* on Aug. 4, examined the inner workings of the ARDA Conference, also known as the Academic Research and Development Association. ARDA is a paper mill—a site that lets academics add their names to already-written scientific papers that are accepted to be published in peer-reviewed journals.

Paper mills don't usually state the names of journals that papers will be published in, but ARDA does so, making it easier to study, says Reese Richardson, a biologist and research integrity expert at Northwestern University who coauthored the new analysis.

In January 2018, ARDA listed 14 journals on its site; by March 2024, that figure had shot up to 86 publications. That's despite efforts by databases like Web of Science and Scopus to deindex titles found to be cooperating with paper mills. Paper mills sometimes bribe journal editors to get them to publish poor-quality papers on which researchers have purchased authorships.

Deindexing is often seen as an effective tool to counteract paper mills since academics are keen to publish in journals indexed in databases like Web of Science and Scopus. But Richardson says the strategy isn't working as well as it should because paper mills seem to be growing in size and number.

Nandita Quaderi, editor in chief for Web of Science and senior vice president of the analytics firm that operates it, Clarivate, says the study uses outdated data for Web of Science. "Since December 2021, we have de-listed a further 187 journals for failing our editorial requirements, including many journals flagged in the study," she says in a statement emailed to C&EN. "Our ability to identify untrustworthy journals has greatly improved since 2023, which is when we introduced proprietary AI tools that look for signs of anomalous behaviour, questionable content (including papermill content), and irrelevant citations."

Another indicator of the scaling up of organized scientific fraud, Richardson says, is that in recent years, academic publishers have started issuing more retractions in batches. "Publishers seem to recognize that the problem is systematic production of fraudulent science," he notes.

Just last week, for instance, Retraction Watch reported that the academic publisher Frontiers Media retracted 122 studies published by five of its journals after finding that networks of authors and editors manipulated citations and conducted peer review without disclosing conflicts of interest. Frontiers notes in a statement that it is not the only publisher struggling with faulty papers. The company says its research-integrity team has identified more than 4,000 papers posted on other publishers' journal sites that are linked to an "unethical" network.

Mark Robinson, corporate media relations manager at the scholarly publisher Taylor & Francis, tells C&EN that the firm is also dedicating "significant resources" to screening papers before peer review. "However, tackling the root causes that encourage and enable misconduct must be a priority for the whole academic community: institutions, funders, and publishers. This includes addressing the pressures on researchers around career advancement, rewards, and incentives," Robinson adds.

Richardson and his colleagues estimate that the number of papers being pumped out by paper mills is doubling every 1.5 years, whereas the number of retractions is doubling only every 3.5 years. He and his team predict that only 15–25% of paper-mill products will ever be retracted.

"Our main takeaway is we have no clue how large the problem is and how quickly this may overtake legitimate literature," Richardson says. "But it's clear that it's already surpassed in scale the intervention measures that are designed to contain it."—**Dalmeet Singh Chawla, special to C&EN**

Drug Development

AstraZeneca quietly shelves COVID-19 preventive

The company will not pursue FDA approval for sipavibart

AstraZeneca has elected not to move forward with a COVID-19 preventive in the US, despite approvals in other parts of the world, after resistance emerged in a late-stage clinical trial.

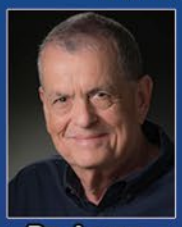
AstraZeneca spokesperson Fiona Cookson told C&EN Aug. 1 that the company is "not currently pursuing a [Biologics License Application] in the US for COVID-19 prophylaxis" for sipavibart, a monoclonal antibody designed to prevent symptomatic COVID-19 in people whose immune systems are compromised.

Not everyone is able to mount a sufficient immune response to COVID-19, even if they've been vaccinated. One analysis of electronic health records in England showed that while immunocompromised people made up 4% of a random sample, they accounted for 21.7% and 21.9% of COVID-19-related hospitalizations and deaths, respectively (*J. Infect.* 2025, DOI: 10.1016/j.jinf.2025.106432).

Monoclonal antibodies have been an attractive second line of defense in the past, but the molecules are susceptible to viral evolution. Today, there are no such drugs authorized as COVID-19 treatments in the US, and only one authorized for prophylactic use—Invivyd's Pemgarda, or pemivibart.

AstraZeneca completed a Phase 3 trial last spring testing sipavibart in 3,349 people who were at least 12 years old and were considered immunocompromised, including organ transplant

SIPS 2025, in Honor of Nobel Laureate in Chemistry, Prof. Aaron Ciechanover



Dr. Aaron Ciechanover

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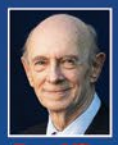
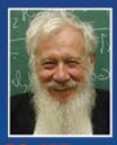
2011 - Chemistry



Harvey J. Alter
2020 - Medicine

Gregg L. Semenza
2019 - Medicine

Joachim Frank
2017 - Chemistry



Robert J. Aumann
2005 - Economics

Aaron Ciechanover
2004 - Chemistry

Rudy A. Marcus
1992 - Chemistry

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recipients, cancer patients, people with HIV, and people on immunosuppressive medications. Participants were randomly assigned to take sipavibart, a combination of Evusheld and placebo, or placebo alone. Evusheld is another monoclonal antibody made by AstraZeneca for COVID-19 prevention, but its US authorization was revoked in 2023 after resistance emerged.

Across a broad swath of viral variants, 7.4% of people who'd taken sipavibart ended up with symptomatic COVID-19, compared with 10.9% in the comparator group. But sipavibart's protective effect was almost completely lost in participants who got COVID-19 that was caused by a SARS-CoV-2 variant with the Phe456Leu mutation in the virus's spike protein (*Lancet Infect. Dis.* 2025, DOI: 10.1016/S1473-3099(24)00804-1).

This mutation has become widespread, and Cookson confirms that AstraZeneca's decision not to seek US approval was "due to the high prevalence of SARS-CoV-2 variants that are resistant to sipavibart."

Sipavibart is approved under the name Kavigale in Japan and the European Union. But uptake has been minimal.

The company is not the first to step back from a COVID-19 antibody this year. The start-up Generate:Biomedicines deprioritized two monoclonal antibodies for internal development in April, meaning those medicines will move forward only if an external partner chooses to license them.—**Rowan Walrath**

Business

Earnings slip at major firms

Agriculture was a bright spot for BASF; Dow resorts to cutting dividend

Earnings reports from two of the world's largest chemical companies—BASF and Dow—indicate that, despite a few rays of hope, second quarter results won't be good for the chemical industry.

BASF's sales fell 2.1% during the quarter versus the same period last year. Its net income tumbled 81.6%.

The company's chemical business, particularly the petrochemical unit, continues to be a drag on its financial results because of oversupply in that sector. Chemical sales dropped 11.9% compared with the year-earlier quarter.

The German chemical maker had a couple of bright spots. Its agricultural unit busted out with a 21% volume increase for the second quarter. The gains came from BASF's crop protection chemicals, herbicides in particular. Earnings for the segment nearly doubled.

▲ **BASF's acetylene plant in Ludwigshafen, Germany. The firm's chemical business has been struggling.**

BASF is legally separating its agricultural unit and plans to conduct an initial public offering in the business by 2027.

Surface technologies, which houses BASF businesses such as automotive catalysts, also had a banner quarter on the back of improving car sales. The segment posted an 11.0% increase in sales.

BASF says it is getting inquiries from industrial and private equity firms interested in buying its coatings business, another area it wants to exit. The unit, which includes the firm's automotive coatings business, generated sales of $4.4 billion in 2024. "The process is well on track," BASF CEO Markus Kamieth told analysts July 30.

The same overcapacity that weighed on BASF's results was brutal for Dow. The company posted a 7.4% decline in sales, driven mostly by lower prices. It lost $800 million in the quarter; sales in its largest unit—packaging and specialty plastics—were down 8.9%.

Dow is already shutting three plants in Europe and conducting a round of layoffs to save money. The company has now resorted to slashing its dividend as well, by 50%. Dow prides itself on its dividend and has paid one every quarter since 1912.

"With $2 billion moving out every year in a fixed dividend, that really put some handcuffs on us from a capital flexibility standpoint at this part of the cycle, and reducing that dividend gives us more flexibility to do other things as we navigate through," Dow CEO Jim Fitterling told analysts in a conference call July 24.—**Alex Tullo**

CREDIT: BASF

Regulation | Story of the month

EPA rejects key finding underpinning US climate rules

Energy secretary cites new DOE report on climate change by known climate denialists to justify repeal

Indianapolis—US Environmental Protection Agency administrator Lee Zeldin announced July 29 that the agency is moving to repeal its 2009 endangerment finding, the legal and scientific basis for federal climate regulations under the Clean Air Act, which says that greenhouse gas (GHG) emissions endanger public health and welfare. The EPA's proposal to repeal the endangerment finding also includes removing GHG emission limits for light-, medium-, and heavy-duty vehicles that rely on the endangerment finding.

"If finalized, this will amount to the largest deregulatory action in the history of the United States," Zeldin said at a commercial truck dealership in northeastern Indianapolis alongside Secretary of Energy Chris Wright.

Speaking in the un-air-conditioned warehouse for Kenworth of Indianapolis to a group of Kenworth employees, members of the Indiana Motor Truck Association, local politicians, and members of the local press, Zeldin said that when the endangerment finding was created in 2009, the creators made "many, many, many mental leaps."

When the Clean Air Act was initially written, it took into account only the "air toxics," or compounds that directly affect human health when breathed in. Zeldin called the interpretation of the Clean Air Act to include GHGs, which are not directly toxic to humans by themselves, an "extremely creative and unprecedented spin," and an

▲ **US Environmental Protection Agency administrator Lee Zeldin speaks on the phone during an artificial intelligence summit on July 23, 2025, in Washington, DC. On Tuesday July 29, Zeldin announced the EPA's proposal to rescind the scientific and legal justification to regulate greenhouse gas emissions at a commercial truck dealership in Indianapolis.**

CREDIT: JULIA DEMAREE NATHANSON/AP PHOTO

"oversimplified statement to the point that it's just not accurate." The Obama administration EPA's scientific justification for the endangerment finding relied on assumptions and made predictions for climate change that ended up not being true, Zeldin said.

But many environmental experts disagree with Zeldin's assessment. "Every credible summary of the science since 2009 has not only supported the original finding but expanded the list of ways in which climate change is already harming human health," John Balbus, former deputy assistant secretary for climate change and health equity at the US Department of Health and Human Services said at an online press briefing July 29. It was hosted by the environmental advocacy groups the Environmental Defense Fund, the Union of Concerned Scientists, and the Natural Resources Defense Council following Zeldin's announcement.

Energy Secretary Wright said at the Kenworth event that he had commissioned a study on climate change by scientists that "have not been cowed by the politics of climate change." The report, "A Critical Review of Impacts of Greenhouse Gas Emissions on the U.S. Climate," which was also released July 29, was written by five scientists. Three of the scientists, John Christy, Steven Koonin, and Roy Spencer, are known for their climate change–denialist stances. The report includes arguments such as previous studies' overinflation of current and future GHG emission trends, the ambiguity of human GHG emissions' effect on climate change, and the underestimation of solar activity's contribution to warming. Many of these arguments have been debunked by the large consensus of climate scientists.

Wright said the report is an honest, credible, fact-driven assessment of climate change. "What we really want to do is bring climate science into the same realm we treated all science in the past," which is to use critical thinking and base government decisions on data and facts, he says. "We want to end the cancel-culture Orwellian future we've been in, where climate change is just not treated as a serious science, it's treated as a political force to silence and shame people," Wright said.

The report went through internal peer review at the US Department of Energy, Wright says. When C&EN pressed for details of this peer review, Wright did not give specifics. "It was brief," he said. "We wanted to get this document out there." The DOE report did not go through an external peer review, but it's now open for public comment.

There will also be a public comment period for the EPA's proposal to rescind the endangerment finding, a process that "has not taken place on the endangerment finding over the past decade and a half," Zeldin said, which would be since 2010. The endangerment finding has been open for public comments twice—once in 2008 and once in 2009—and garnered more than 580,000 public comments. The EPA also held two public hearings on the finding before it was finalized in 2009.

Environmental groups and government officials have vowed to fight against the EPA's proposal.

"This antiscience proposal will be challenged," Rachel Cleetus, climate and energy policy director and lead economist at the Union of Concerned Scientists (UCS), said at the EDF/UCS/NRDC online press briefing.

US representative Zoe Lofgren (D-CA) calls the EPA's actions "delusional and unscientific" in a statement. "EPA's longstanding endangerment finding that greenhouse gases fuel climate change and are bad for human health is based on an overwhelming amount of scientific evidence," she says. "As the lead Democrat of the House Science Committee, we will fight back on this."—**Leigh Krietsch Boerner**

CREDIT: SHUTTERSTOCK

▲ **The US Environmental Protection Agency plans to re-register dicamba herbicides for use on genetically modified soybeans and cotton. Dicamba drift has led to numerous complaints about damage to conventional soybeans (pictured).**

Pesticides

EPA advances new dicamba herbicides

Proposal permits year-round use of drift-prone chemical

In a win for big agriculture, the US Environmental Protection Agency (EPA) plans to register three new dicamba herbicides for use on soybeans and cotton that are genetically modified to tolerate the weedkiller. The proposal, announced July 23, comes despite two court orders, in 2020 and 2024, to ban such uses because dicamba is prone to volatilizing and harming nontargeted plants on neighboring land.

The EPA began allowing use of dicamba herbicides on genetically modified soybeans and cotton in 2017 to combat weeds that are resistant to the widely used herbicide glyphosate.

Every year since, states have received numerous complaints about dicamba damaging nonmodified soybeans, orchards, gardens, and trees. Dicamba is volatile, particularly when temperatures spike, making it prone to drifting off-site.

Environmental groups sued the EPA, which led a federal appeals court to overturn the approval in 2020. But just a few months later, the EPA registered dicamba again for use on genetically modified soybeans and cotton. Environmental groups sued the agency again, and in 2024, the US District Court for the District of Arizona ordered the EPA to cancel the 2020 registration.

The EPA's latest proposal would put the controversial herbicide, made by BASF, Bayer Crop Science, and Syngenta Crop Protection, back on the market for use on genetically modified soybeans and cotton with a few new restrictions. The formulations have not changed, but the labels have, in terms of how and when the products can be applied. Specifically, the proposal limits applications to no more than two per year. It also requires that the herbicide be mixed with an EPA-approved drift-reduction agent and pH-buffering agent to reduce volatility, at increasing amounts as temperatures increase. No spraying would be allowed at temperatures above 95 °F.

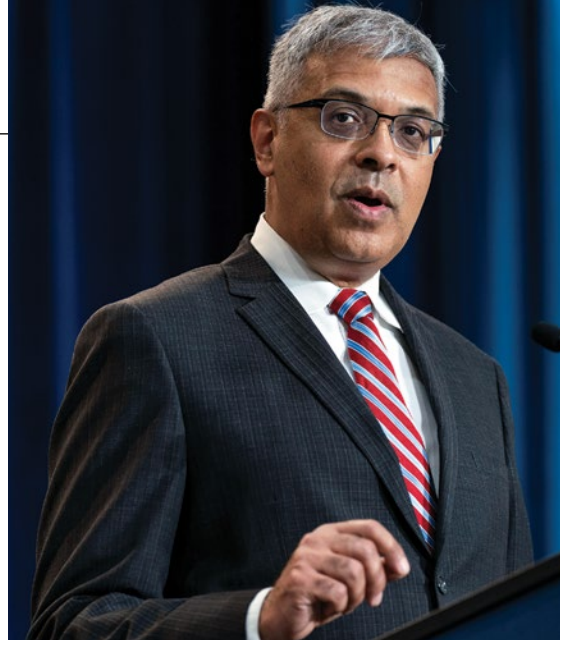
Initially, when Bayer applied for registration of its new dicamba product, called KHNP0090, the company suggested an annual cutoff date of June 12 for soybeans and July 30 for cotton, after which the herbicide could not be sprayed until the following growing season. The EPA's proposal would allow year-round applications but require temperature-dependent restrictions, such as reducing how much of a field is sprayed or prohibiting certain mixtures at higher temperatures.

Environmental groups say the restrictions do not go far enough. "If we allow these proposed decisions to go through, farmers and residents throughout rural America will again see their crops, trees and home gardens decimated by dicamba drift, and natural areas like wildlife refuges will also suffer," Bill Freese, science director at the Center for Food Safety, says in a statement. "EPA must reverse course and withdraw its plans to re-approve this hazardous herbicide," he says.

Bayer claims in an emailed statement that low-volatility dicamba herbicides provide "tremendous value to soybean and cotton farmers across the U.S." The company says it will continue to work diligently to ensure these herbicides remain an option for soybean and cotton farmers next year and beyond.

The EPA is accepting comments on its proposal until Aug. 22. The agency is particularly interested in hearing from farmers about operational challenges posed by managing temperature-dependent volatility. The EPA acknowledges that the proposed mitigation measures are not standard.

In response to questions about why the agency is moving ahead with the registrations despite two court orders canceling similar ones, the EPA says it "has conducted a robust human health risk assessment for these proposed products and has not identified any human health or dietary risks of concern. Also, EPA has developed new, additional proposed mitigations to minimize impact to certain species and the environment."—**Britt E. Erickson**



▲ **NIH director Jay Bhattacharya speaks at a news conference on April 22, 2025.**

CREDIT: ASSOCIATED PRESS

Research Funding

NIH director denies banned word list

Bethesda Declaration signers insist that a list exists and further criticize new policies

On July 21, US National Institutes of Health (NIH) staffers met with NIH director Jay Bhattacharya to discuss their concerns about policy changes implemented under the second Donald J. Trump administration. Bhattacharya set the meeting in response to the Bethesda Declaration—an open letter signed by many NIH staffers calling out the policy changes.

At the meeting, NIH staffers criticized overzealous word searches being applied to grant reviews by the Department of Government Efficiency (DOGE). Staffers say that grants recommended for funding are being turned down because they include language deemed to be at odds with the administration's priorities.

Bhattacharya told staff members at the meeting that there is no list of banned words, according to one attendee who spoke on condition of anonymity for fear of retribution.

"We know for a fact that's not the case," the source says, regarding Bhattacharya's denial. They

say they've seen grants turned down for containing specific words that in context are completely irrelevant to administration priorities, which suggests a banned list.

Mollie Manier, an NIH staffer who also attended the meeting and spoke with C&EN, confirmed that Bhattacharya suggested that there was no list of banned words. But she also said program officers work with applicants to remove words and phrases they think are getting flagged during the final phase of the funding process—because they know grants containing certain words tend to get rejected, regardless of a grant's scientific merit.

Specifically, it's the grants that contain language supposedly related to diversity, equity, and inclusion (DEI) that get rejected. But staffers claim that many of these grants were not in fact DEI initiatives but instead aimed at assessing the health of minority populations. According to Manier, Bhattacharya says he "wants underrepresented minorities to succeed and to be healthy in the way that he wants nonminorities to be healthy," but he takes issue with setting funds aside for specific groups or awarding funds based on an applicant's racial, ethnic, or gender identity.

The NIH has not awarded anyone grant funding on the basis of their race, ethnic, or gender identity, Manier says. Instead, she says that the NIH notices of funding opportunities sometimes invite grant applicants from underrepresented groups. But their applications go into a pool with all other grant applicants. Funding is then awarded to applicants purely based on their grant's scientific merit, according to Manier. But she says special invitations to apply are still a point of contention for Bhattacharya.

Staffers also raised concerns about the recent cancellation of clinical trials and other recent actions by the Trump administration

When grant payments that were funding ongoing clinical trials were abruptly canceled, it resulted in a "failure to adhere to ethical standards in order to keep research participants safe," Manier tells C&EN. Follow-up care for research participants was paused, and treatments to people in trials were delayed. NIH staffers told Bhattacharya at the meeting that such moves can't happen again.

Staffers also raised concerns about recent reductions in the NIH workforce, telling Bhattacharya that the layoffs have overburdened those who remain and left voids in mission-critical positions. The Department of Health and Human Services (HHS), which includes the NIH, has said that it intends to cut 20,000 employees and that half of those cuts would come via layoffs. According to Manier and the anonymous source, Bhattacharya said he doesn't have the power to rehire for those jobs. He could seek an exemption from a reduction in force for certain mission-critical positions, he said, but he couldn't get an exemption for everyone.

The NIH budget process and current spending plans also came up for discussion.

To spur the NIH to spend its remaining budget before the fiscal year ends, the Office of Management and Budget is directing the NIH to shift toward awarding multiyear grants, in which a grant is funded in its entirety up front in a single fiscal year rather than divvied out over multiple fiscal years. But NIH staffers told Bhattacharya that this policy will drastically reduce the number of grants it can fund each year. "What that means is you take a chunk of money that would normally go to four different labs and you give it to one," Manier says.

▲ **Protesters gathered on the National Institutes of Health campus after the meeting between director Jay Bhattacharya and Bethesda Declaration signers.**

Since the release of the Bethesda Declaration, staffers at other federal agencies, including the National Science Foundation, the Environmental Protection Agency, and NASA, have followed suit with open letters of their own as more scientists and others push back against what they perceive as existential threats to US research and strategic priorities.

But while the meeting set by Bhattacharya may be the start of a longer conversation between agency leadership and staffers in which some of the latter's concerns get resolved, Manier isn't optimistic that's the case. "I don't realistically think anything is going to come of it, but it's an opportunity for Jay to get to know us and understand we have a depth and breadth of expertise that he could be utilizing."

The anonymous source, on the other hand, is more optimistic that something may come of the meeting. "There are multiple requests, and every ask comes with a deadline where we can know if it was heard or not," they say. "We asked for an official policy that says there are no word searches. If that could come in 2 weeks, then we would know that we were heard."

The NIH had not responded to a request for comment by the time this story was published on the C&EN website.—**Max Barnhart, with additional reporting by Laurel Oldach**

CREDIT: ROSA LAFER-SOUSA

NEXT STOP, GRADUATE SCHOOL

How the Graduate School Readiness Boot Camp is supporting the next generation of Chemists

By Melba Newsome, *C&EN Brandlab*

Selome Banini has dreamed of a career in the chemical sciences for as long as he can remember. But despite graduating from the University of Minnesota with a BA in chemistry, he struggled to land a job in the field or get into a graduate school program. In January, Banini was finally hired—as a lab technologist at Eurofins Scientific, an international life sciences company that performs analytical testing, in Minneapolis.

Though he was happy to find a well-paying job, he still hoped to earn an advanced degree in the chemical sciences, which he calls his first love. "You can break down how everything in this world works and then apply it everywhere," Banini says. "I feel like I wouldn't be satisfied with just having a bachelor's degree. It feels redundant to have all this knowledge in chemistry and not use it for something greater. Undergraduate work is very guided and doesn't really expand your mind, whereas graduate school will help you think outside the box."

In the fall of 2024, Banini had earned a spot in the American Chemical Society 2025 Graduate School Readiness (GSR) Boot Camp. He hoped the hands-on workshop in Houston would provide the edge he needed to craft a successful graduate school application.

The GSR Boot Camp is a 3-day, all-expenses-paid workshop created through a partnership between the Genentech Foundation and the ACS Bridge Program. Founded in 2020, the Bridge Program is a national initiative designed to assist students understand their education and career options, including pursuing advanced degrees or navigating to different sectors of the workforce. The GSR Boot Camp aims to demystify the often daunting and confusing graduate school application process by providing targeted support and resources. It helps attendees showcase themselves in a way that sets them apart and explains why they are a good fit for a graduate school program.

"This program provides students with the tools to articulate their personal narrative, craft competitive graduate school and fellowship applications, and expand and nurture their professional network," says ACS Bridge Program portfolio manager Dawn Holt, Ph.D., Psy.D. "Through workshops, discussions, and consulting sessions, the boot camp supports students in identifying their unique strengths, experiences, motivations, and goals."

A crucial element of the GSR Boot Camp's success lies in its emphasis on self-discovery; a clear understanding of personal values and strengths is necessary for navigating the graduate school journey. Before attending the in-person workshop, participants engage in a virtual session to start this process;

that session includes a CliftonStrengths assessment to help participants understand their talents.

The in-person workshop then builds upon this foundation, guiding students through a series of activities aimed at deepening their understanding of their strengths, specifically within the context of graduate school. One project challenges students to think of their strengths as superpowers and work collaboratively in small groups to create a superhero character by selecting one of each group member's top five CliftonStrengths and merging them. For example, a group at the 2025 Boot Camp combined the strengths "woo," "futuristic," "discipline," and "achiever" to conceptualize Dash, a superhero dedicated to forging cohesive graduate school plans by fostering group camaraderie and community.

> **I feel like I wouldn't be satisfied with just having a bachelor's degree. It feels redundant to have all this knowledge in chemistry and not use it for something greater. Undergraduate work is very guided and doesn't really expand your mind, whereas graduate school will help you think outside the box."**
>
> **Selome Banini**
> *GSR Boot Camp participant, 2025*

In her featured session at the 2025 GSR Boot Camp, Gloria Thomas Fuller, Ph.D., an associate professor at Southern University and A&M College, advised participants on everything from choosing the right graduate program to securing funding. This "Graduate School Reality Check" session offered practical advice on how applicants can sell themselves by highlighting their accomplishments while still coming across as coachable and adaptable. Fuller also demonstrated how these strengths can be leveraged to clarify each student's why—their intrinsic motivation for pursuing graduate studies.

University of California, Irvine, senior Cheyenne Begay thought that the 2025 GSR Boot Camp was a stellar event. "The seminar presented an insightful and eye-opening reality check about what's in store for graduate school," she says. "I was especially interested in meeting like-minded peers and building a network of people from across the country who were interested in graduate school."

Begay is among the many GSR Boot Camp attendees who tout their one-on-one interactions with invited faculty members who have experience reviewing graduate applications as a significant benefit. "I had the pleasure of sitting down with Professor Ginger Redd and found her tips about my personal statement to be incredibly helpful," Begay says. "I was able to ask her every specific question about content and formatting I could think of. Professor Redd was able to provide insider tips on what she looks for in graduate school admissions."

Begay plans to spend a year or two in the workforce before pursuing a PhD in nuclear and radiochemistry. "The advice I got about how to transition from industry to graduate school was eye-opening," she says.

All of this resonated with Banini. In the past year, he had come to take his grad school rejection in stride, choosing to regroup, not give up. Fuller's lecture and the entire workshop affirmed that belief, encouraging him to redouble his efforts and stay the course. "I have more experience under my belt now," he says. "Boot camp taught me to take my time, focus, and take it seriously."

Holt has overseen boot camp operations from the applications through post program survey analysis for the past 3-years and believes that 2025, the GSR Boot Camp's fifth iteration, was the best to date. "I'm genuinely proud of how this year's boot camp in Houston turned out,"

> **I was especially interested in meeting like-minded peers and building a network of people from across the country who were interested in graduate school."**
>
> **Cheyenne Begay**
> *GSR Boot Camp participant, 2025*

Holt says. “We were able to use feedback from students and others to craft a cohesive design and build a strong and well-structured program.”

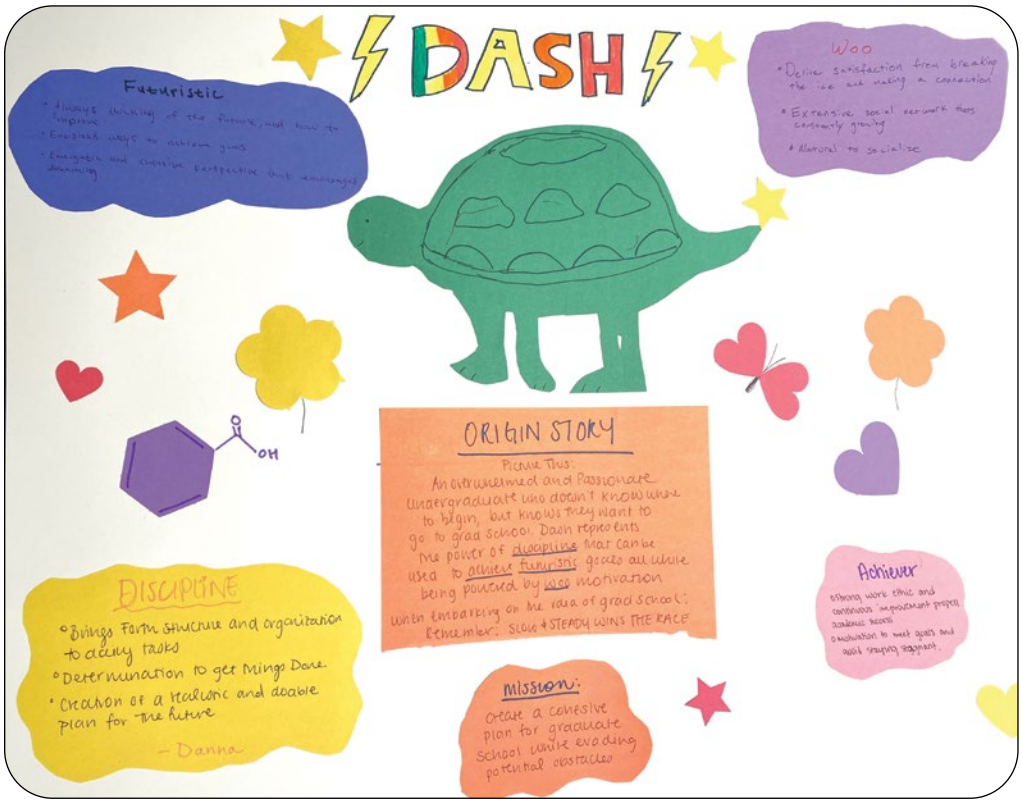
The program has served as a helpful stepping stone for many previous participants. Yolmarie Del Valle had just completed her first research experience in Puerto Rico but was unsure whether she was cut out for graduate school on the US mainland. She saw a post about the 2023 boot camp on Instagram and applied, hoping it would help her answer that question.

Del Valle says the 2023 Atlanta workshop helped her prepare a successful application. Through her conversations with invited faculty reviewers, she learned to identify her unique experiences and express them in a personal statement. The program also significantly boosted her confidence and showed her she was a good fit for an advanced degree program.

“Boot camp made me realize I belong in the graduate school scene and deserve an opportunity like this,” Del Valle says. “Once I realized this, I never looked back.” Now a graduate researcher at the University of Michigan, she says she has recommended the GSR Boot Camp to several people, one of whom participated in the program and was subsequently accepted to graduate school.

Lidia Belete, a graduate student at the University of Arkansas for Medical Sciences who is pursuing a Ph.D. in interdisciplinary biomedical sciences, had a similar experience when she participated in 2023. Since completing her workshop, she has used her experience to give other students considering graduate school a heads-up about what to expect. She suggests they engage with other ACS professionals who could provide insight into their potential career paths. Most importantly, she advises aspiring graduate students to know their why. “Think about why you want to go to graduate school,” she says.

Banini has considered that question and credits the workshop for confirming his desire to pursue an advanced degree. “If you feel like you have something more to offer, you want a more expansive view of your work,” he says. “If more chemistry students pursued an advanced degree, we would be one step closer to new discoveries.”



Dash is a superhero that combined the strengths of “woo,” “futuristic,” “discipline,” and “achiever.”

Credit: The American Chemical Society

Applications for the next Graduate School Readiness Boot Camp will open in August 2025. Visit acs.org/bootcamp for more details

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How chemists can rebuild

After 2025's barrage of US research funding disruptions, new strategies to sustain the field have emerged

Robin Donovan, special to C&EN

Two hundred thousand dollars. That was the number keeping Keana Redfearn up at night as her June graduation approached. She'd been accepted into doctoral chemistry programs—several, in fact. Then came the tailspin of federal funding cuts through the US National Science Foundation (NSF) and US National Institutes of Health (NIH). Her graduate school admissions were quickly revoked, then her undergraduate institution, the University of California, Los Angeles, offered a conditional reinstatement. The terms were strict: She would be a master's student. And she would pay her own way, all six figures of it.

"I'm not rich, and I don't have anyone else to support me," says Redfearn, a first-generation student in organic chemistry. Even the initial offers, which had included tuition and stipends, left her barely able to afford housing. Staring down a graduate school megabill, she panicked and applied to programs in Europe.

Today, she's packing to move from her home in California to Belgium, to continue her studies at KU Leuven. She's not sure if it's a one-way trip or not, only that her stipend will be nearly double what she'd been offered at UCLA and that tuition will be mostly covered. Redfearn's projected rent abroad will be a bit over half what she'd pay in Los Angeles, she says.

"Even though I wasn't ready to make the

CREDIT: ELIA SAMPÒ

KEY INSIGHTS

- Federal funding for US science research has been disrupted dramatically in 2025.
- In the US, more funding sources, including foundations, start-ups, and venture capital, are emerging.
- Other countries are enticing US students and scientists to move abroad, leaving the overall impact on chemistry and science uncertain.

decision, it was kind of my only option," she says. Her classes start at the end of September.

Friends from her graduating class, she reports, are taking a gap year, pursuing teaching, or looking for industry jobs. Others are following Redfearn's lead: "Most of them are actually applying to the same school that I got into."

Since April, the NSF's budget has been in flux as the newly minted Department of Government Efficiency (DOGE) announced plans to cut more than half the agency's budget, then began axing grants. Courtroom challenges have led to judges blocking some of the cuts, such as reimbursement caps for indirect research costs. At press time, the appropriations process to fund federal programs, also for the next fiscal year, which begins in October, is under way. A Senate appropriations committee is hammering out an agreement aimed at restoring NSF funding for the next fiscal year, but the final numbers are far from decided. Research funding from other agencies such as the NIH is similarly uncertain, as are the consequences of an executive order issued on Aug. 7 entitled "Improving oversight of federal grantmaking."

Federal funding remains critical, particularly for basic research, says Scott Delaney, a public health researcher who specializes in climate change at Harvard University. "There is no nonprofit out there waiting in the wings. There's no benevolent billionaire who can fill the void left when the federal government withdraws from scientific research. Industry will not do it. They don't invest in basic research the way that we do it."

Basic research pays dividends. In 2024, economists Karel Mertens and Andrew Fieldhouse reported that a dollar of federal money invested in basic research yields a 140–210% boost in economic and social benefits.

Among early-career scientists, Redfearn is lucky; she has options. But many graduate students and postdoctoral researchers are not only navigating funding cuts. Nearly half of early-career researchers in the US are foreign born and may be facing immigration challenges as well. The available solutions are partial or narrow in scope. Some foundations and universities now offer bridge funding to ease the move from canceled grants to funding that's been secured but has yet to begin flowing. Many scientists have turned an eye to start-ups and are searching for stability in industry jobs, as foundations band together to offer new types of funding. The chaos is not confined to the US, either. Recruitment efforts from Europe to Asia and beyond are targeting academics from science, technology, engineering, and mathematics (STEM) fields, as Redfearn experienced.

▲ **Keana Redfearn stands in front of a building at the University of California, Los Angeles, in May. Redfearn is moving to Belgium to complete her doctoral program in chemistry.**

CREDIT: COURTESY OF KEANA REDFEARN

Finding a way through the upheaval won't be easy, but history reminds us not to underestimate the ingenuity of people whose job is to create new knowledge.

"The chemical industry is one of the most knowledge-intensive industries," says Martha Moore, chief economist for the American Chemistry Council. "There's a tremendous amount of knowledge that is required to make the industry run. There's always going to be a need for engineers and life scientists."

Survival of the elite

The current US funding crisis isn't the first in recent decades, although the NSF and NIH cuts themselves are unique. The 2008 and 2020 economic downturns led to cutbacks, according to researchers at the College and University Professional Association for Human Resources (CUPA-HR), which publishes data on hiring trends.

Jacqueline Bichsel, CUPA-HR's associate vice president of research, says higher education

CREDIT: MELISSA BENDER/NURPHOTO VIA AP

▲ **Dozens of rallies took place across the US on March 7, 2025, including in Washington Square Park in New York City, in support of funding science research.**

responds to budget cuts in three steps: by increasing tuition; by reducing staff; and third, by freezing salary increases. "The same thing happened after the [2008] recession," she says. "The same thing happened after the pandemic, but then, generally, STEM fields will bounce back. I have no idea whether that will happen now."

Much has to do, she adds, with state funding levels, which are currently in flux.

Bichsel expects high performers to flee states with the largest cuts for private universities, which typically offer higher salaries without being "under the thumb" of state government funding or policy mandates. But with the threat to Ivy League players such as Columbia University, which agreed to settle a lawsuit with the Donald J. Trump administration for $200 million to reestablish its federal funding, even well-heeled institutions are at risk. Because community colleges and lower-budget institutions rely less on research funding, and a healthy donor base can partially buffer well-resourced private institutions, Bichsel says public midsize colleges and universities stand to suffer most. Students from groups underrepresented in STEM fields will also be disproportionately affected, Bichsel says. A July report from the Urban Institute think tank found that 90% of canceled NSF grants had a link to diversity, equity, and inclusion (DEI) initiatives.

STEM job searchers may find themselves competing more intensely for available slots, stacking part-time adjunct roles on top of industry jobs, or taking other positions unrelated to their research area, she says.

Even pivoting to teaching demands creativity and determination. Bichsel says adjuncts teach a median of five credit hours per semester, with a median pay per credit of $1,226. So some paths forward mean having one foot in academia and one foot out.

Past economic rebounds have led to the reinstatement of STEM funding. But the 2025 cuts have not been made in response to a recession. Rather than waiting for uncertain funding reinstatements, Bichsel is watching to see how states respond to political pressure. "You're going to see blue states try to hold on to that education funding a lot longer than red states will."

Investing primarily in people

Political stripes aside, the human impact of the funding problem is wide reaching.

"In the sciences, in academia, we have a tendency to think about linear paths," says Cynthia Fuhrmann, an associate professor at the UMass Chan

Medical School. "Instead, this is a really good time to be thinking a little bit differently."

For instance, with an unsettled future, relationships may be more important than concrete plans. Fuhrmann developed a self-directed online tool, myIDP, for career exploration. She still sees "a wealth of opportunities" for scientists but says the pathway from shock to career shift takes patience. Paradoxically, she says, times of career upheaval can yield free time (if not the headspace) needed to explore.

STEM recruiter and career coach Lauren Celano agrees, estimating that STEM job searchers will need 3–6 months to find a new job, even after exploring options and identifying a desired role. "That [estimate] assumes you have an idea of what jobs might be a fit," she says. "In most cases, people apply to a hundred jobs and maybe get a couple interviews," she says. The periods from the end of January to June, plus September through November, are the busiest seasons for STEM job searchers, with an additional burden on international students and postdoctoral scholars because of visa requirements.

Solitary introspection isn't enough. People thinking about career changes "have aha moments where new opportunities arise for them as they think through these things and talk to more people," Fuhrmann says.

With fewer concrete opportunities, networking relationships have gained importance. Carl Bergstrom, an evolutionary biologist at the University of Washington, has decried cuts to grants aimed at recruiting and retaining students from underrepresented groups in particular.

"Comparably small investments to maintain the pipeline now will pay massive dividends . . . Rather than cutting back on funding because of uncertain times, foundations should fund more aggressively than ever," he wrote on Bluesky. Bergstrom himself is a legacy of investment in a STEM pipeline: he was supported by funding from the Howard Hughes Medical Institute through graduate school. In February, HHMI abruptly cut DEI-related funding, and in May, it froze a fellowship program.

"My funding priority remains people and programs that nurture the science and technology ecosystem in the US. This—not merely generating novel discoveries—is the true role and function of our federal science funding efforts," Bergstrom says.

Meanwhile, Fuhrmann points to opportunities in science journalism, policy, nonprofit, government, and even business roles like project management as lesser-explored options for those leaving academia. Peaceful, introspective time is key. You don't want

US VISA AND FUNDING BARRIERS HIT EAST AFRICAN RESEARCHERS HARD

Across Kenya and the wider East African region, a growing number of students and early-career scientists say new US visa policies and funding restrictions are derailing academic dreams. For many, the opportunity to study, conduct research, or even attend conferences in the US is slipping out of reach, cut off not by merit but by paperwork and politics.

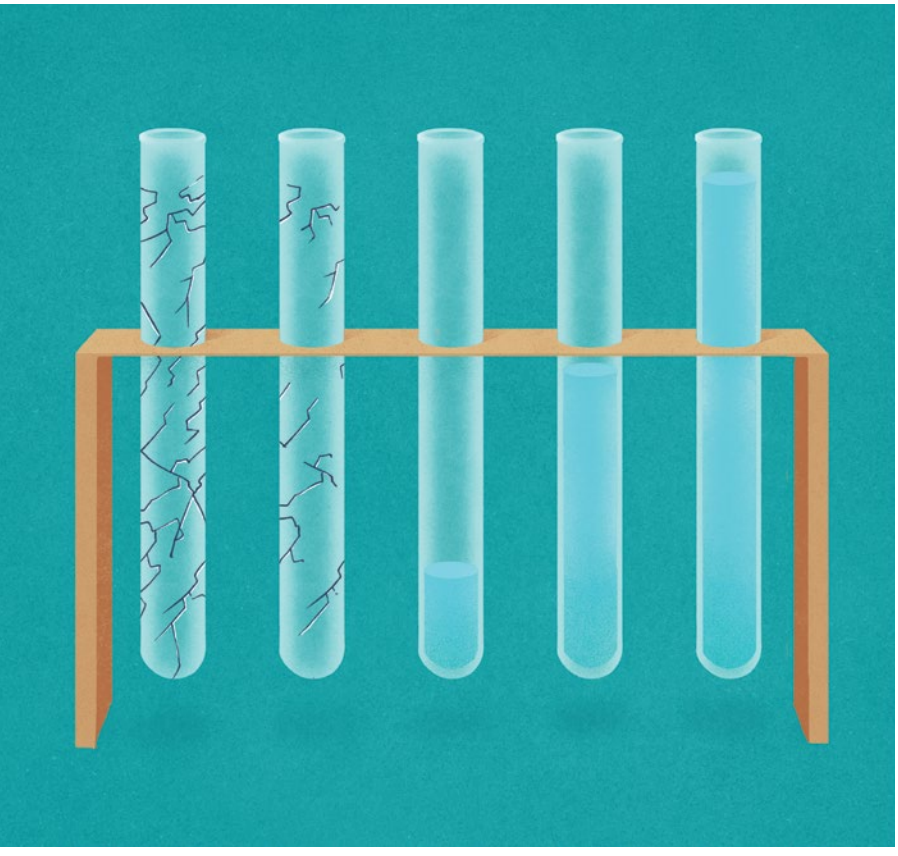
In May 2025, the US temporarily suspended new visa interviews for international students and scholars. Though interviews resumed a few weeks later, new rules introduced sweeping vetting processes, including mandatory disclosure of social media accounts and in-person interview requirements even for renewals. The result has been a wave of delays and rejections, with African applicants among the most severely affected groups. A Ugandan chemist who had planned to begin a joint fellowship with a US laboratory this September now remains in limbo, waiting for a visa interview slot that keeps being rescheduled. A Kenyan computer scientist reported receiving a full grant to speak at a major tech conference in the US, before being abruptly denied a visa at the embassy. Both researchers requested anonymity to avoid retribution.

Collaborative research projects between African institutions and US universities are also stalling. Uganda's leading research institution, Makerere University, has been severely affected by the US funding freeze under Donald J. Trump and has halted several major projects.

Amid such frustrations, literary communication professor Egara Kabaji at Masinde Muliro University argues that Africans should create their own wealth, funding, and institutions. He explains that the real problem is not visa denials but that Africa is not fixing what's broken at home.

"This is a wake-up call. If you have the skills and key knowledge, and someone successfully denies you a visa, that shouldn't crush you. Instead, make your universities. Create a good environment. Build your economy. Don't beg for visas elsewhere. About funding cuts from the US, let's remember that this is taxpayers' money. They can choose to give it or not. We should not cry about it," Kabaji says.

Although the US remains a top destination for researchers in chemistry and other science fields, its increasingly closed doors could push talent elsewhere or even out of research entirely, with uncertain impacts in East Africa and beyond.—**Scovian Lillian, special to C&EN**



CREDIT: ELIA SAMPÒ

to "feel like you're running from fire to fire," Celano says.

Celano has received more requests for meetings with her since NSF announced its cuts. She's expecting a shift from short-term survival strategies to scientists branching out for funding, including exploring partnerships they hadn't previously considered with companies connected to their sector. Celano sits on the board of the National Tay-Sachs and Allied Diseases Association, which helps fund research on these rare diseases at a few universities. "We've seen firsthand, actually, researchers in our particular space that have had to stop their research because they didn't have funds," she says. For diseases or niche fields with few hopes for research otherwise, such cuts can be devastating.

Celano's had coaching clients reach out to rare disease foundations, which may not bring in the same amount as a big government grant, she says, "but it might be enough to get to the next thing." She's hopeful that foundations and private offices administering funds for wealthy families will consider specialized research donations, knowing that advancing pet causes depends on research funding.

States support their own

Lesser-known US federal programs offer Small Business Innovation Research (SBIR) grants to boost business growth. As a supplement, some states match federal grants, target in-demand industries, or support students and entrepreneurs in underrepresented groups. State leaders hope the resultant economic growth will create jobs and businesses that feed tax revenue back into state coffers.

Funding tends to be specific to businesses or researchers who live in the state offering the support. For example, the One North Carolina Fund Small Business Program distributions average approximately $2.5 million per year, according to John Hardin, executive director of the North Carolina Office of Science, Technology, and Innovation (NCOSTI). His office's two-part mission includes advising the state legislature and the governor on policy related to STEM and providing direct funding support to STEM-related businesses.

There is still upheaval. The national nonprofit State Science and Technology Institute (SSTI), which supports SBIR programs, announced in late July that it would not host an annual conference in 2025 because of the "continued uncertainty in the . . . funding landscape." On the same day, the US Small Business Administration launched new funding for regional centers that support small businesses with technological innovations, including funding partnerships in manufacturing, microreactors, artificial intelligence, and semiconductors, among other areas.

Some state-level programs reimburse cash-strapped start-ups the money it takes to compile lengthy federal funding applications, which Hardin says can cost $15,000 just to prepare and submit. "If they win one of those highly competitive federal grants, we then can match that funding with some state funding," Hardin says.

The roughly 15% of applications that are funded, according to Hardin, are technologically and intellectually sound, with some commercial potential. "They could create the greatest thing in the world, but if it can't be sold, then it wouldn't be funded under this program," he says.

"We haven't seen an uptick yet" in applications, says Chris Schmidt, NCOSTI's grants manager. She expects some lag, as future funding for federal agencies has been uncertain. Her program has $2 million in annual funding, with another chunk of cash that varies each year. So far, she has seen an increase in incentive applications—funding that reimburses applicants for expenses incurred in preparing a federal application.

Schmidt says the North Carolina program is one of about 20 state-level programs that help start-ups win SBIR funding across the US; SSTI has a map-based listing of state-by-state offerings that include some non-SBIR programs with comparable benefits.

Ohio's Third Frontier program offers support similar to that of the North Carolina program. It also goes a step further by working with existing

start-ups via incubators and accelerators that provide business plans, legal help, and local mentors. The program offers funds to match contributions from private investors.

California has more-specialized offerings among its state-based funding. Its Energy Commission Awards, funded through state utility fees, support projects such as electric vehicle infrastructure, green energy, light-duty hydrogen infrastructure, and more.

"Many scientists have created technologies that have unexplored or unrealized commercial potential," Hardin says. "Scientists don't have to go it alone." University offices of technology commercialization, which may be called technology transfer or research commercialization departments, can be a conduit from academia to the start-up world.

Venturing into the unknown

At the University of Colorado Boulder, a commercialization arm called Venture Partners serves as a bridge. "Our mission is to get the research that happens on campus out into the real world," says director of venture development Amy Dodenhoff.

When a researcher makes a discovery, they'll submit an invention or copyright disclosure to Dodenhoff's office to get started. Venture Partners workers either find industry partners to license the technology or support inventors in launching a start-up to commercialize it. Some start-ups are led by scientists themselves, typically professors, postdoctoral researchers, or graduate students. But occasionally, Venture Partners will match scientists with an entrepreneur who can facilitate a start-up launch. In a single fiscal year, Dodenhoff says her office worked with about 180 different inventions.

Venture Partners networking events have had record attendance in recent months, even though, like so many paths forward for scientists, Dodenhoff says hers is a partial solution, one that pairs investors seeking profits with the chance to invest in new inventions and companies.

She notes that venture capitalists are beginning to consider how cuts to research funding may slow or disrupt the supply of future start-up candidates. Venture Partners has already started to invest in preseed funding for start-ups licensing CU Boulder technology.

For scientists shy to make the leap into start-ups, Dodenhoff says attending conferences outside of academia is a first step. She also recommends NSF's I-Corps start-up accelerator, which runs a 7-week boot camp for practicing customer interviews and business planning. Funding for the research teams (PDF) who attend I-Corps programs is continuing, as is financial support for existing (but not new) university-led hubs that help administer the program, according to an NSF insider who requested anonymity to avoid retaliation. But funding for new hubs is, as of press time, not included in 2026 budget proposals, according to an NSF spokesperson. At least one venture capital firm has begun funding people and projects earlier in the process. New York–based Lux Capital is offering $15,000 grants and mentorship to support undergraduate students pursuing degrees in physical, computational, or life sciences. It also reports earmarking $100 million for academic scientists "confronting their own crossroads."

A marketing graphic for a Lux Capital hotline features a billboard that reads, "Scientist? Injured by funding cuts? Let Lux Help." This ambulance-chasing illusion worked: a representative of the company turned down a C&EN interview, explaining they're too inundated with calls from scientists. The company's landing page states that part of its goal is to stop China from eclipsing the US in several emerging technologies.

Like Dodenhoff, Lux Capital leaders clearly think there is more start-up potential than academics realize: "Perhaps a grant just got cut: what are the alternatives?" its website reads. "Maybe a visa didn't get renewed: could our global network of scientists and peers find another way forward?"

> "My funding priority remains people and programs that nurture the science and technology ecosystem in the US. This—not merely generating novel discoveries—is the true role and function of our federal science funding efforts."
>
> **Carl Bergstrom,** evolutionary biologist, University of Washington

Ohio's Third Frontier program offers support similar to that of the North Carolina program. It also goes a step further by working with existing start-ups via incubators and accelerators that provide business plans, legal help, and local mentors. The program offers funds to match contributions from private investors.

California has more-specialized offerings among its state-based funding. Its Energy Commission Awards, funded through state utility fees, support projects such as electric vehicle infrastructure, green energy, light-duty hydrogen infrastructure, and more.

"Many scientists have created technologies that have unexplored or unrealized commercial potential," Hardin says. "Scientists don't have to go it alone." University offices of technology commercialization, which may be called technology transfer or research commercialization departments, can be a conduit from academia to the start-up world.

CREDIT: JEANNE ACCORSINI/SIPA VIA AP IMAGES

Wanted: Foundation partnerships

Like scientists, foundations often seek new collaborations and better ways of doing their work when funding shifts. In a March 2025 survey, the Council on Foundations asked its members what operational changes they'd consider (PDF). The top answer, given by 54% of the 183 foundations that responded, said they hoped to partner with other funders. The next two most popular responses were shifting priorities to address funding cuts and being more flexible in grantmaking. Twenty percent of foundations planned no changes.

In the chemical sciences, "We certainly hear from our applicants and grantees that there is more interest in our grant programs and that they will need to rely on funding from private sources," says Courtney Mattox, the Welch Foundation's assistant director of grant programs. But the foundation is not announcing any changes in response to the NSF cuts specifically. Elsewhere, partnerships have started to materialize. The Kapor Foundation, the William T. Grant Foundation, the Alfred P. Sloan Foundation, and the Spencer Foundation partnered to offer grants up to $25,000 for urgent needs, such as data collection and analysis. According to the Spencer Foundation website, early-career researchers had priority. Only formerly NSF-funded researchers were eligible for the awards; applications are now closed.

▲ Several countries began or expanded efforts to recruit scientists after changes to US funding in 2025. French president Emmanuel Macron spoke at the launch of the Choose Europe for Science at the La Sorbonne amphitheater on Monday, May 5, 2025.

Gary Chou, an expert in entrepreneurship, start-ups, and social innovation, points out that philanthropy began as a way to fill in funding gaps. But today's challenge, he says, may be more aligned with a tech start-up mentality: funded projects that fail are opportunities to learn. Chou is the founder of Orbital, a start-up consultancy that builds communities for peer coaching and helps founders and funders share ideas.

He's not optimistic that foundations will step up to fund science in a meaningful way. "You need a lot more room and a lot more time for things to emerge that are unexpected. That is a lot more expensive than the kind of focused, capital-efficient, iterative problem-solving" common in the nonprofit world.

Chou suggests that a private patronage model could be more likely. "If you believe that we are shifting towards a more oligarchic society, and you put yourself into that future state, then everything is patronage," he says. In other words, the

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PRESIDENTIAL SYMPOSIA AND EVENTS

Dr. Dorothy J. Phillips
ACS President

www.acs.org/pres

SATURDAY, AUGUST 16, 2025

11:00 am-2:00 pm
ACS Kids Zone [cosponsored by CCA]
Ronald Reagan Building – 1300 Pennsylvania Avenue, NW

MONDAY, AUGUST 18, 2025

8:00 am-11:55 am
Creating Beauty: Exploring the Intersection of Chemistry and Cosmetics
Walter E. Washington Convention Center – Room 140B

8:00 am-5:40 pm
Innovations in Natural Polymer Science for Sustainable Agriculture and Food Security [sponsored by POLY and cosponsored by PRES, AGFD, CARB, ENVR & PMSE]
Walter E. Washington Convention Center – Room 143B

8:00 am-5:45 pm
Nuclear Today and Tomorrow
Walter E. Washington Convention Center – Room 208 A/B

8:00 am-5:50 pm
Revolutionizing Energy Storage: AI, Automation, and Advanced Modeling Driving Next-Gen Breakthroughs [sponsored by ENFL and cosponsored by PRES]
Walter E. Washington Convention Center – Room 156

8:45 am-12:00 pm
Preventing the Reemergence of Chemical Weapons [cosponsored by IAC]
Walter E. Washington Convention Center – Room 202A

12:00 pm-2:00 pm
Creating Beauty: Exploring the Intersection of Chemistry and Cosmetics Poster Session
Walter E. Washington Convention Center – Hall C

12:00 pm-2:00 pm
Innovations in Natural Polymer Science for Sustainable Agriculture and Food Security Poster Session
Walter E. Washington Convention Center – Hall C

12:00 pm-2:00 pm
Nuclear Today and Tomorrow Poster Session
Walter E. Washington Convention Center – Ballroom A/B Foyer

2:00 pm-6:00 pm
Water-Soluble Polymer: From Foundational Science to Finished Products [sponsored by COMSCI]
Walter E. Washington Convention Center – Room 201

6:00 pm-8:00 pm
Nuclear Today and Tomorrow Reception
Walter E. Washington Convention Center – Ballroom A/B Foyer

TUESDAY, AUGUST 19, 2025

8:00 am-12:00 pm
Celebrating 75 years of the National Science Foundation [sponsored by COMSCI]
Walter E. Washington Convention Center – Room 201

8:00 am-12:00 pm
Green Polymer Chemistry and Sustainability: Polymer Degradation and Recycling [sponsored by POLY and cosponsored by PRES, AGFD, CELL & PMSE]
Walter E. Washington Convention Center – Hall D-Room 6

8:00 am-12:00 pm
Preparing/Educating the Next-Generation of Chemical Technical Professionals
Walter E. Washington Convention Center – Room 208A/B

8:00 am-12:00 pm
The Future of Measurement Science: Instrumentation, Methods & Data Analytics Panel Discussion [sponsored by ANYL and cosponsored by ENVR, MEDI & ORGN]
Marriott Marquis Washington, DC - Liberty Salons N, O & P

8:00 am-5:10 pm
Rock Stars of Regenerative Engineering [sponsored by PMSE and cosponsored by PRES and COMSCI]
Walter E. Washington Convention Center – Room 202A

12:00 pm-2:00 pm
Green Polymer Chemistry and Sustainability Poster Session
Walter E. Washington Convention Center – Hall D

2:00 pm-6:00 pm
Green Polymer Chemistry and Sustainability: Polyesters, Polyurethanes, and Rubbers [sponsored by POLY and cosponsored by PRES, AFGD, CELL & PMSE]
Walter E. Washington Convention Center – Hall D-Room 6

2:00 pm-6:00 pm
The Future of Measurement Science: Instrumentation, Methods & Data Analytics [sponsored by ANYL and cosponsored by ENVR, MEDI & ORGN]
Walter E. Washington Convention Center – Ballroom C

6:00 pm-8:00 pm
The Future of Measurement Science: Instrumentation, Methods & Data Analytics Reception [sponsored by ANYL and cosponsored by ENVR, MEDI & ORGN]
Walter E. Washington Convention Center – Ballroom C

WEDNESDAY, AUGUST 20, 2025

8:00 am-5:30 pm
Black Chemists Breaking Scientific Barriers [sponsored by ORGN and cosponsored by PRES, INOR & POLY]
Walter E. Washington Convention Center – East Salon F

2:00 pm-5:40 pm
Beyond the Bunsen Burner: Navigating Tough Conversations and Situations [sponsored by the CINF & CPRC and cosponsored by PRES]
Walter E. Washington Convention Center – East Salon C

THURSDAY, AUGUST 21, 2025

8:00 am-11:45 am
Beyond the Bunsen Burner: Navigating Tough Conversations and Situations [sponsored by the CINF & CPRC and cosponsored by PRES]
Walter E. Washington Convention Center – East Salon C

8:00 am-6:00 pm
Green Polymer Chemistry and Sustainability: Biobased Materials, Polysaccharides, and Thermosets [sponsored by POLY and cosponsored by PRES, AFGD, CELL & PMSE]
Walter E. Washington Convention Center – Hall D-Room 6

SYMPOSIA AND EVENTS RECOMMENDED BY THE ACS PRESIDENT

SUNDAY, AUGUST 17, 2025

Global Virtual Symposia [individual symposia sponsored by BIOL, ENFL, ENVR, MEDI, ORGN, PHYS & PMSE]

MONDAY, AUGUST 18, 2025

8:00 am-6:00 pm
CME-NASA: Elevating Polymer Chemistry to New Heights-Polymers for Future Space Missions
Walter E. Washington Convention Center – Hall D-Room 10

Global Virtual Symposia [individual symposia sponsored by BIOL, ENFL, ENVR, MEDI, ORGN, PHYS & PMSE]

Virtual Graduate Students Symposia in Asia-Pacific Region [individual symposia sponsored by ANYL, ENFL & ENVR]

TUESDAY, AUGUST 19, 2025

8:00 am-12:00 pm
CME-NASA: Elevating Polymer Chemistry to New Heights-Polymers for Future Space Missions: Reimagining Chemistry for the Space Age
Walter E. Washington Convention Center – Ballroom C

2:00 pm-6:00 pm
CME-NASA: Elevating Polymer Chemistry to New Heights-Polymers for Future Space Missions
Walter E. Washington Convention Center – Hall D-Room 10

Global Virtual Symposia [individual symposia sponsored by BIOL, ENVR, MEDI, ORGN, PHYS & POLY]

Virtual Graduate Students Symposia in Asia-Pacific Region [individual symposia sponsored by ANYL, ENFL, ENVR, I&EC & POLY]

WEDNESDAY, AUGUST 20, 2025

Global Virtual Symposia [individual symposia sponsored by BIOL, CHAS & PHYS]

Virtual Graduate Students Symposia in Asia-Pacific Region [individual symposia sponsored by AGFD, I&EC & POLY]

THURSDAY, AUGUST 21, 2025

Global Virtual Symposia [individual symposium sponsored by BIOL]

Virtual Graduate Students Symposia in Asia-Pacific Region [individual symposia sponsored by AGFD & CELL]

SCAN ME

right billionaire could, at whim, decide to throw funding toward a pet project.

Chou's own company, Orbital, is also a self-described independent research project. The primary question his research asks is: How can what works in start-ups be applied to other sectors? The tech sector was unique, he says, in adopting the internet as a place to share successes and failures, allowing outsiders to borrow and build on existing data. In contrast, very few nonprofits share donor lists or disclose funding failures. And few foundations, Chou says, are pushing out findings about grantmaking activities that don't pan out. Science itself, he says, has the same problem of cherry-picking success stories to share. "There's a lot of opacity, and it leads to a lot of people re-creating the wheel."

Like Dodenhoff, Lux Capital leaders clearly think there is more start-up potential than academics realize: "Perhaps a grant just got cut: what are the alternatives?" its website reads. "Maybe a visa didn't get renewed: could our global network of scientists and peers find another way forward?"

'Academic asylum'

Across international borders and oceans, there's less concern about repeating history and more energy behind capitalizing on US funding cuts. From Europe to Asia, nations have cast a hungry eye on the wave of talent being washed from US institutions.

"Foreign institutions are really heavily recruiting academic scientists to come work for them at high salaries," says CUPA-HR's Bichsel.

Some programs originate from foreign governments. One example is China's High-End Foreign Talents Plan, one of many Chinese initiatives aimed at attracting talent. The program recruits elite professionals, including artists, athletes, and researchers. The program's targets include postdoctoral researchers under 40 at "top universities abroad," college and university professors, and winners of awards such as the US National Medal of Science or the US National Medal of Technology and Innovation.

In France, Aix-Marseille University launched its Safe Place for Science program to recruit top US scientists in response to cuts by the NSF. The program is funding 21 of 298 total scientists who applied this year (applications are now closed), thanks to university funds. A hoped-for €13 million ($15.2 million) in funding from the French government would allow it to welcome at least 10 more scientists, according to Clara Bufi, head of communications for Aix-Marseille University. The governmental funds are funneled through France's Choose France for Science program.

"Our only wish is that the obstacles which are currently making scientists look elsewhere for academic freedom are alleviated as quickly as possible," Bufi says. "In the meantime, we want to be able to provide academic asylum for those who need it, as long as we can." The first group of awardees included representatives from astrophysics, medicine, the life sciences, and the humanities.

Bufi hopes to see similar programs throughout Europe to support people the Safe Place for Science program couldn't fund. The European Union has also created initiatives, such as Choose Europe, which has pledged a total of €500 million ($583 million) from 2025 to 2027 to attract researchers from abroad. Launched in May, the program's website features job and funding search functions, as well as applications for European Research Council grants, which Bufi says were recently extended from 5 to 7 years.

Top scientific talent may quickly secure opportunities outside the US. But building or relocating displaced research capacity and infrastructure, especially in the form of interconnected, multilaboratory research ecosystems, will take time.

Self-starting under duress

For scientists like Harvard's Delaney, foreign options aren't a choice. "My kids are 7 and 9. We're set up in Boston. We're not going to move," he says, despite recently noticing a "great job" available in his field in Stockholm. "It's not as simple as just picking up your office and moving somewhere else. Scientists are humans just like everybody else."

Delaney is a unique expert on recent NSF funding cuts. Also a lawyer, he cocreated the Grant Witness (formerly Grant Watch) database with colleague Noam Ross. Delaney's lawyering past made him realize the importance of cataloging all grants canceled, even if funds were later reinstated. And as a scientist, he knew how to gather and compile data.

"The fact that the grant was reinstated doesn't mean there was no harm, no damage. A lot of times, when science stops, it can't be recovered in the same way," Delaney says. The project became even more personal when Delaney's own grant was canceled and added to the database. At Grant Witness, scientists submit reports of canceled grants, which are uploaded to a Google spreadsheet without naming the filer, including, in early April, whistleblowers who announced early funding cancellations.

How the global scientific ecosystem adapts to such disruption will depend on a multitude of factors: whether scientists can stay in STEM or build a path to return to it, and whether they can pivot, collaborate, and keep the doors open, financially and emotionally, long enough for new breakthroughs to arrive.

For now, scientists like Redfearn are pressing on, opening emails like the one she received from UCLA while packing for Belgium. Its subject line read, "The Loss of Federal Funding is a Loss for America." ⬢

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Why India can't kick its coal habit

Country's embrace of coal-to-chemicals technology only doubles down on its addiction

Aayushi Pratap, C&EN staff

KEY INSIGHTS

- India plans to increase its domestic coal production in the coming years to generate electricity and make chemicals.
- Some worry that the country's rising dependence on coal will deter it from its goal of becoming net zero by 2070.
- Experts argue that coal consumption must be accompanied by increased use of carbon capture technologies.

At a United Nations climate change conference in Glasgow, Scotland, 4 years ago, Indian prime minister Narendra Modi made an ambitious pledge. In the presence of over 120 other global leaders, he set 2070 as India's target year for net-zero emissions of carbon dioxide and other planet-warming gases.

For India, the world's third-largest emitter of greenhouse gases, meeting that goal will require moving away from coal, the country's primary source of energy, and embracing renewable and other low-carbon resources. Along those lines, the government has made significant strides in building its renewable energy capacity over the past decade. Several ambitious investments in the fields of solar energy and green hydrogen have recently made headlines.

But as the country's energy demand grows, renewable energy adoption hasn't

CREDIT: ANINDITO MUKHERJEE/BLOOMBERG

▲ **Two workers install solar panels on the roof of a residential apartment in Kochi, a city in Kerala, a state in southern India.**

CREDIT: R. S. IYER

been accompanied by a decrease in reliance on coal, a fossil fuel that generates more CO_2 per unit of energy produced than other nonrenewable sources, such as natural gas and oil.

In fact, India's coal use is on the rise and not just for power generation. The government is investing in and incentivizing industrial projects based on coal gasification, in which coal is oxidized in the presence of steam at high temperatures. The process creates synthesis gas, a mixture of carbon monoxide and hydrogen.

The concoction, also known as syngas, serves as a raw material for basic chemicals such as methanol and ammonia. Syngas can also be used to produce olefins and other petrochemicals, though this approach is practiced mainly in China and South Africa. The Indian government is bullish on syngas technology, and officials have set a goal of gasifying 100 million metric tons (t) of coal, about 10% of the country's annual coal consumption, by 2030.

Gasifying coal to make chemicals is not much better in terms of greenhouse gas emissions than burning coal—and much worse than making those chemicals from oil or natural gas. India relies heavily on oil, natural gas, and methanol imports, which not only are expensive but also contradict Modi's vision of making the country self-sufficient. Although many policy experts defend India's coal consumption as an economic right to utilize a domestic resource, it's clear that the country, at least for now, is not moving in the direction of carbon neutrality.

An appetite for coal

In the world's most populous country, home to nearly 1.4 billion people, coal remains the dominant energy source. It is used mainly in thermal power plants, where it is burned to generate electricity. The generated power is supplied to residences and industrial plants through India's expansive electric grid. About 75% of the country's power comes from coal, according to the nation's coal ministry.

"India doesn't have a lot of oil and gas, but it has plenty of coal. Over the years, the country has developed ways to harness it," says Sandeep Pai, head of research design and strategic engagement at Swaniti Initiative, a think tank that works at the intersection of climate action and economic development.

In 2023, India had an estimated 378 billion t of coal reserves, making it the fifth-largest country in terms of coal deposits. With a rapidly growing economy, India will continue to rely on coal, experts say.

Partha Sarathi Bhattacharyya, the former chairman of Coal India, the world's largest government-owned coal producer, says India's per capita energy consumption is among the lowest in the world, but he expects the number to grow in the years ahead as the country becomes more prosperous. An analysis by World Population Review, a website with a goal of making demographic data more accessible, found that per capita 2023 energy consumption in the US was 277 gigajoules (GJ), compared with 27.3 GJ in India. "A population of 1.4 billion people can aspire [to] quite a lot," Bhattacharyya says.

Nikit Abhyankar, co–faculty director of the India Energy and Climate Center at the Richard and Rhoda Goldman School of Public Policy at the University of California, Berkeley, notes that electricity demand in India is growing at an average rate of 7% per year. "In the residential sector, the highest

▼ **A cyclist passes by a coal-fired thermal power plant in the northern Indian state of Uttar Pradesh.**

CREDIT: MAYANK MAKHIJA/NURPHOTO

demand comes from air conditioners," he says.

India's renewable energy capacity, which this year is five times more than it was in 2014, accounts for about 46% of the country's overall power-generation capacity, but the reality is that less than 20% of the actual power consumed in India comes from renewables. With energy demand set to grow rapidly in the coming years, Bhattacharyya says, renewable sources will struggle to significantly increase their share of the country's power-consumption requirements.

While India aims to generate 50% of its electricity from nonfossil sources by 2030, it also plans to ramp up coal production by as much as 42% during the same period, according to the Institute for Energy Research, a think tank based in Washington, DC. And one reason for the expected increase in the use of coal is that increasing amounts of it will be converted into syngas.

Coal-to-chemicals strategy

In the agricultural industry, syngas is used to make ammonia, a key fertilizer and raw material for other fertilizers. In the petrochemical industry, syngas can be reformed into methanol, which is a fuel as well as a feedstock for producing certain plastics, textiles, and pharmaceuticals.

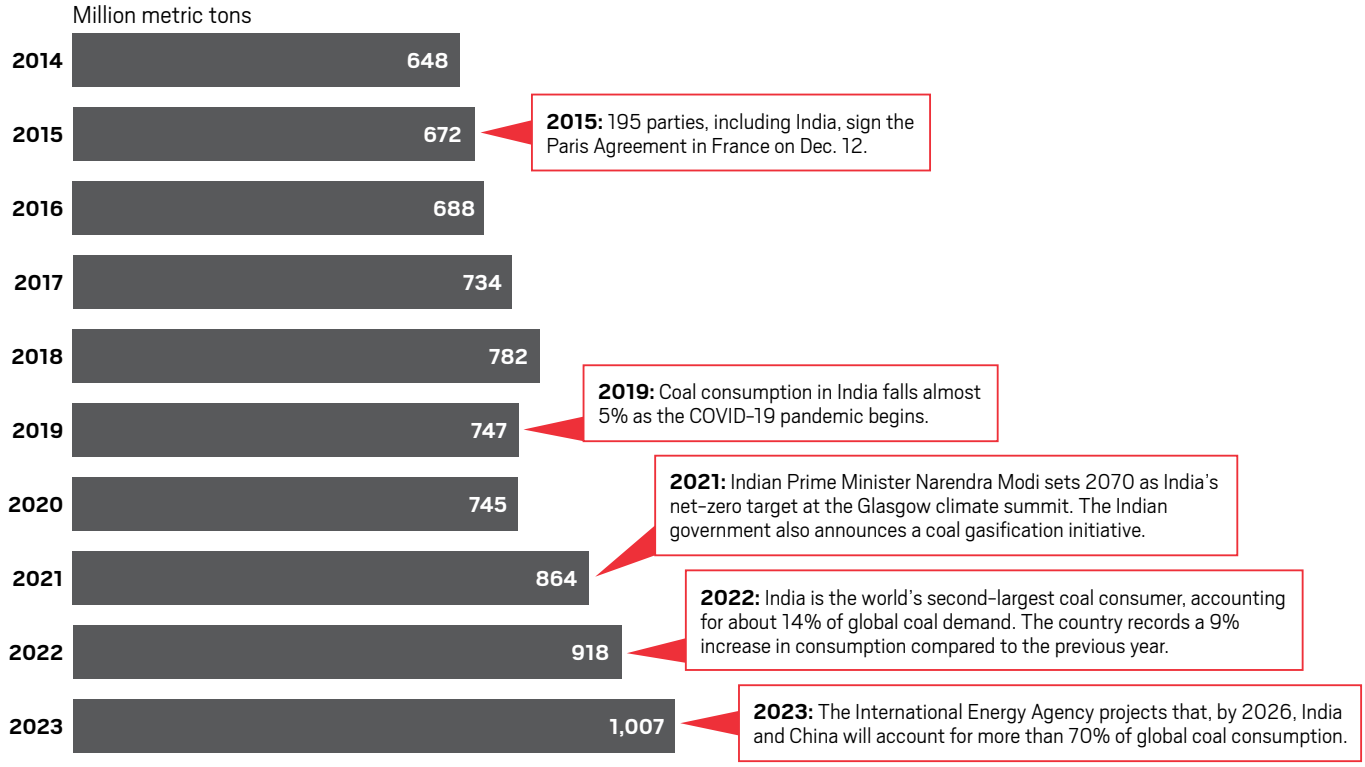
In most of the world, the starting material for syngas is natural gas. But last year, the Indian government approved $1 billion in financial incentives for coal-gasification projects, with the aim of reducing dependence on imported fuel and chemicals and supporting indigenous technology.

Jindal Steel, a steel and power producer and a key player in India's private sector, secured $66 million in government incentives for a 2-million-t-per-year coal-gasification project in India's eastern state of Odisha. The company will use the syngas in the manufacture of sponge iron.

New Era Cleantech received $116 million for a coal-gasification project in western Maharashtra. Using the technique, the company aims to produce 330,000 t per year of ammonium nitrate

Coal is king

Coal consumption in India has nearly doubled in 10 years.



Source: NITI Aayog. **Note:** Years refer to fiscal years that begin in April and end in March of the next year.

CREDIT: VIJIT BAGH

▲ **Heavy traffic on a street in Mumbai, a city in India's western state of Maharashtra.**

and 100,000 t per year of hydrogen.

State-run companies are also pursuing coal gasification. Coal India has partnered with Bharat Heavy Electricals, also a state-run company, to set up an ammonium nitrate plant. The investment is expected to yield 660,000 t per year of ammonium nitrate, used both as a fertilizer and in explosives. In another project, NLC India, a company under the Indian Ministry of Coal, plans to produce methanol from syngas.

To some experts, these investments are a step in the right direction, given that the Indian chemical industry relies heavily on imports of key feedstocks. "Right now, India imports 90% of its methanol from the rest of the world," says Sonal K. Thengane, an associate professor in the Department of Hydro and Renewable Energy at the Indian Institute of Technology Roorkee.

Thengane says coal gasification offers India the opportunity to reduce its reliance on imports and continue raising its standard of living toward the levels enjoyed in Europe and the US. "With coal reserves lying idle in our own country, it doesn't make sense to spend money on importing other cleaner fuels from those countries which are mainly responsible for the climate. It is simply not a sensible idea," he says.

Although coal gasification is not the best option for the environment, it produces fewer emissions than burning coal, Thengane says. Others argue that coal gasification still generates significant greenhouse gas emissions and works against Modi's net-zero vision.

Joe Hittinger, project manager for chemicals at Global Energy Monitor, a nongovernmental organization that crunches energy-related data, says that producing methanol from coal is significantly more carbon intensive than making it from

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natural gas. "The emissions intensity is around five times higher from coal to methanol versus natural gas to methanol," he says.

International pressure to change

Hittinger says he understands the raw-material-independence rationale for the gasification projects, but he worries that the resulting emissions will be detrimental to climate goals for both India and the world. "India will almost certainly not meet its own climate goals if they don't consider lower-carbon ways to produce these chemicals," he says. Furthermore, approaches like coal gasification need to be fitted with carbon capture technologies, which are still in the early stages of development, Hittinger adds.

Despite India's coal-gasification goals, the primary outlet for the fossil fuel remains the power sector. And for years, India and China, the world's largest coal consumers, have faced immense pressure to transition away from fossil fuels, but neither country has yielded.

At the 11th hour of the 2021 Glasgow summit, India and China opposed a final communiqué stating that coal should be phased out. India's environment minister at the time took to the floor and said, "How can anyone expect that developing countries make promises about phasing out coal and fossil fuel subsidies? Developing countries still have to deal with their poverty-reduction agenda."

Kaushik Deb, executive director of the Energy Policy Institute's India team at the University of Chicago, says that any pressure on India from rich countries is appalling, as India's per-capita carbon emissions are lower than most of theirs. "Even if India tripled its electricity grid, it wouldn't be enough to maintain a quality of life that the developed countries have. It won't match what the US or China have," he says. Any talk by richer countries of pressuring India to reduce its coal consumption amounts to "climate imperialism," he adds.

The Indian government has set a target of doubling non–fossil fuel energy capacity to 500 GW by 2030, but transitioning away from fossil fuels, particularly coal, is not easy when plenty is available in the country's backyard, says Shreyas Shende, a senior research associate focusing on South Asian security, energy, and public policy at the Net Zero Industrial Policy Lab at Johns Hopkins University. "Purely from an equity perspective, India's argument could be, why should it constrain its carbon space and sort of kneecap its economic development prospects at the altar of international cooperation?" he says.

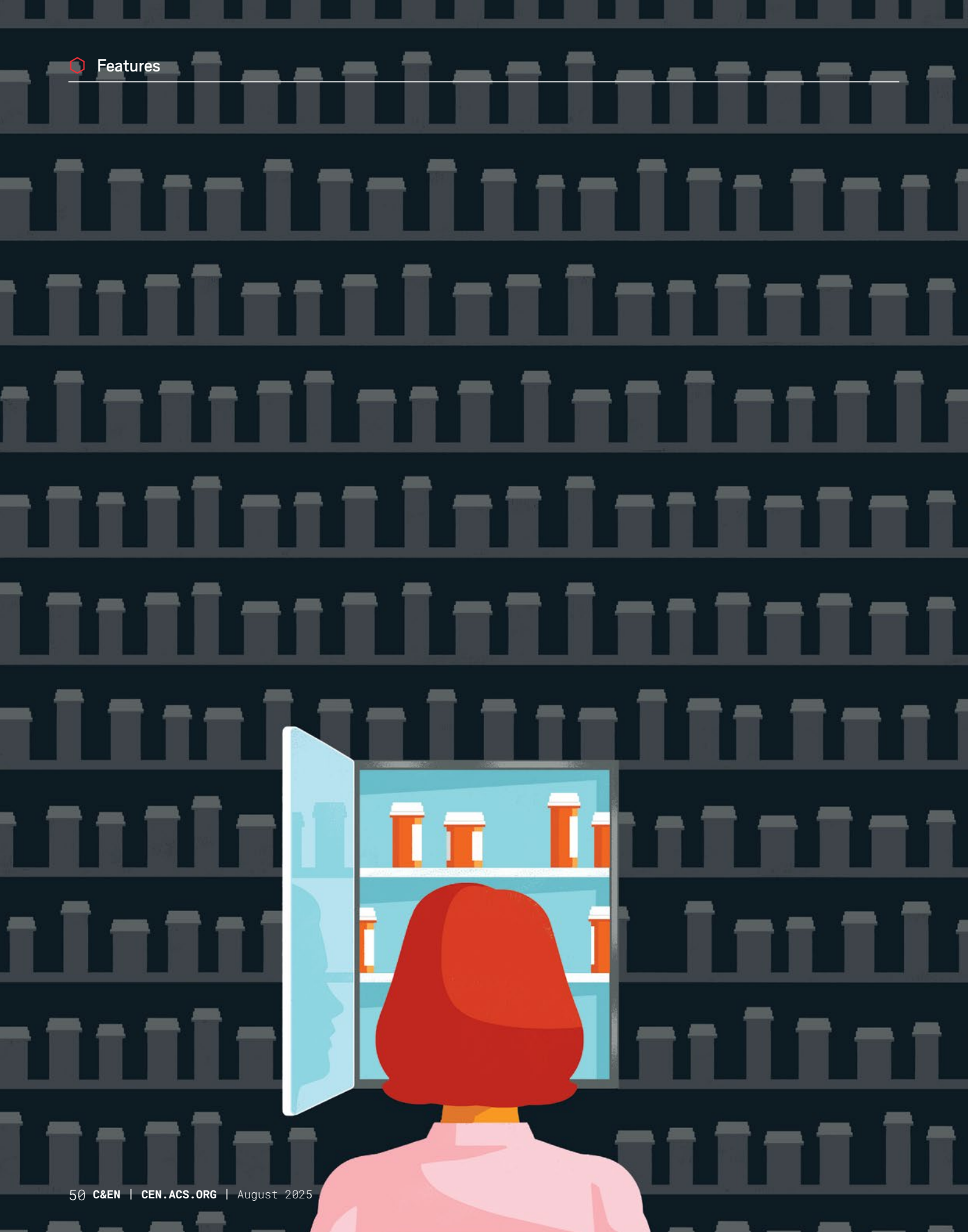
Until wealthier countries, historically the largest emitters of greenhouse gases, disburse capital in the form of climate finances to countries such as India, meeting a collective goal of keeping global warming under control will be difficult, Shende says. And such funding is scarce. He points to the deliberations at COP-29, in Baku, Azerbaijan, in 2024, as evidence of the difficulty of obtaining climate finances.

"Developing countries had asked for trillions of dollars to help mitigate climate change and move to cleaner energy, but rich countries agreed to give much less than that while at the same time failing to meet existing climate-finance commitments," he says.

> "Locking into technologies such as coal gasification will not resolve India's carbon-emissions problem. It will create a larger monster that we'll have to deal with later on."
>
> **—Henna Khadeeja,** research analyst, Global Energy Monitor

Shayak Sengupta, a senior research associate at the Center on Global Energy Policy at Columbia University's School of International and Public Affairs, notes that as the world gets warmer, electricity demand will only keep growing. For India, which is already experiencing increased bouts of heat waves, the need will be especially pronounced. "No matter how many renewables you add to the national electricity grid, they can't keep up with the demand increases," Sengupta says. "For now, India will expand its coal capacity."

India's growing use of coal, whether for electricity generation or chemical production, is going to lead to increased CO_2 emissions in the coming years. And Henna Khadeeja, an India-based research analyst at Global Energy Monitor, says these emissions will continue to cause global warming. "Locking into technologies such as coal gasification will not resolve India's carbon-emissions problem," Khadeeja says. "It will create a larger monster that we'll have to deal with later on." ⬢



No drug left behind

Biotech, pharma, and nonprofit organization leaders ponder how to move abandoned drug candidates to patients

Bethany Halford, C&EN staff

In the race to get drugs to patients, not every promising candidate that clears the initial hurdle of Phase 1 safety trials makes it to market. Some wipe out because of safety concerns that emerge later. Some don't pass the high bar of efficacy. Even those that clear those obstacles sometimes get abandoned, not for scientific reasons but because of business decisions.

In the past few years, biotechnology companies, with the help of patient advocacy organizations, have rescued several of these promising molecules from big pharma's dustbin, gotten them to patients with rare diseases, and even made money in the process. But can this feat be reliably repeated? Executives are trying to figure out if the successes of the past point to a sustainable model for rescuing shelved assets in the future.

Andrew W. Lo, a professor of finance at Massachusetts Institute of Technology, is looking at ways to facilitate the commercialization of compounds shelved for business reasons and is part of an effort to build a clearinghouse for them. He says moving those molecules from big pharma to a biotech to develop "is a great way of taking advantage of essentially a head start and being able to make use of assets that are right now just gathering dust and not really helping anybody."

Mirdametinib makes it to market

Take the story of mirdametinib, a small molecule that was once almost scrapped but found its way to market. Mirdametinib's success is due in part to the efforts of Annette Bakker, CEO of the Children's Tumor Foundation (CTF), a nonprofit dedicated to improving outcomes for people with the painful nerve tumor conditions neurofibromatosis and schwannomatosis.

Bakker had been keeping tabs on mirdametinib for years, going back to the days when it had just a number: PD-0325901. She had followed the compound's progress through preclinical studies and early clinical trials as a treatment for neurofibromatosis type 1 (NF1).

The drugmaker Parke-Davis had originally developed the compound as a potential cancer drug. The molecule came under Pfizer's aegis when it acquired Parke-Davis in 2000. Bakker and the CTF began to take a more serious interest in mirdametinib around 2014, after they saw data from a study conducted by the NF Clinical Trials Consortium and funded by the Congressionally Directed Medical Research Programs. The study showed that the molecule held promise for treating NF.

But another NF1 treatment was going through clinical trials at the same

KEY INSIGHTS

- Pharmaceutical companies often choose not to advance drug candidates for business reasons, rather than because of safety or efficacy concerns.
- These compounds could still help some people, so biotech and patient advocacy groups are looking for ways to move them through clinical trials.
- Mirdametinib is a recent successful example of a shelved drug candidate that eventually made it to market, as a treatment for the tumor disorder neurofibromatosis type 1.

CREDIT: CHRIS GASH

time mirdametinib was. That compound, selumetinib, was developed by AstraZeneca and Merck & Co. and approved in 2020 by the US Food and Drug Administration for children with NF1. It's marketed as Koselugo.

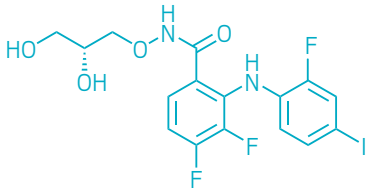
As selumetinib approached approval, Bakker worried about what would happen to mirdametinib. Her intuition as a biochemist who had previously worked in industry told her that Pfizer was going to deprioritize its NF1 program. Mirdametinib would end up collecting dust, even though it had the potential to help patients as a complement to selumetinib.

Mirdametinib and selumetinib are different chemotypes, which is to say their molecular structures differ. "I think it's always good to have multiple molecules with similar mechanisms, with different chemotypes, and not to shelve one drug for the other, because if, God forbid, the original company is not interested anymore, then suddenly we go from one to zero," Bakker says.

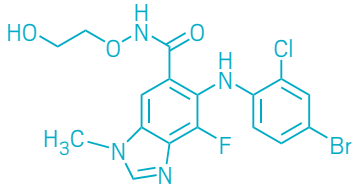
Bakker recalls reaching out to Pfizer executives and asking them not to give up on mirdametinib. The molecule was too important to the NF1 community, she told them. She eventually bent the ear of Pfizer's chief medical officer at the time, Freda Lewis-Hall. "It took us some time, but we convinced her that this was a good application of this drug and that this drug should not die," Bakker says.

Lewis-Hall, who is now retired from Pfizer, says the firm was already planning to spin off a company that could develop assets that had stalled at Pfizer. "What would happen if we identified a number of medicines or potential medicines that met high unmet need, that that were far enough along in development so that we would know the answer to our question in years, not decades?" she says. "And so we put a group of those things together, and then asked ourselves, 'What would it take to build a company that would take those forward?'"

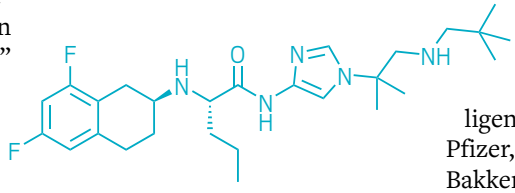
In 2017, SpringWorks Therapeutics launched with $103 million in funding from Pfizer and other investors. Its portfolio included the shelved Pfizer molecules mirdametinib and the desmoid tumor treatment nirogacestat.



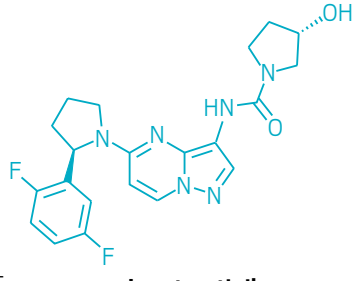
Mirdametinib



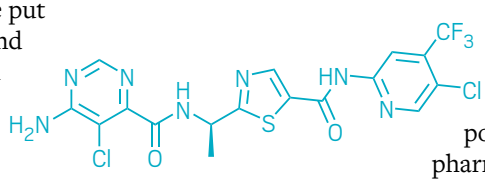
Selumetinib



Nirogacestat



Larotrectinib



Tovorafenib

Lewis-Hall estimates that 200 people working at Pfizer volunteered their spare time to help make SpringWorks a reality. For example, she says, they organized data from the sidelined drug candidates so that they were in good shape to hand off. "These were people around the company that were enthusiastic and committed to finding a pathway for these medicines to get to patients who needed them."

Jim Cassidy, chief medical officer at SpringWorks, says the CTF also assisted the company by helping shepherd mirdametinib through clinical trials. "Remember, COVID happened in the middle of this, and we had real trouble finding good sites and collecting patients," he says. "CTF held our hand, helped us find patients, helped us advertise the availability of the study."

This February, the FDA approved mirdametinib as a treatment for NF1 in children and adults. The therapy, which is marketed under the name Gomekli, is expected to have $564 million in annual sales by 2030, according to GlobalData's Pharma Intelligence Center. "That's not a lot of money for Pfizer, but that's a lot of money for a biotech," Bakker says. Perhaps more telling of the work SpringWorks accomplished, Merck KGaA announced in April that it was buying the company. The $3.4 billion deal closed July 1.

The right conditions for rescuing drug candidates

Mirdametinib is not an isolated example. Larotrectinib, a tissue-agnostic cancer treatment, was originally developed by Array BioPharma in the early 2000s. The compound languished for years before Loxo Oncology licensed it in 2013. In 2017, Bayer agreed to jointly develop larotrectinib with Loxo in a deal worth up to $1.5 billion. The FDA approved larotrectinib in 2018, and Bayer markets it as Vitrakvi. Eli Lilly and Company acquired Loxo for $8 billion in 2019.

Likewise, Takeda Pharmaceutical had plans to shelve tovorafenib, a Raf kinase inhibitor that Biogen and the now-defunct biotechnology firm Sunesis Pharmaceuticals developed for melanoma in the early 2000s. Takeda licensed tovorafenib 2011, but it performed poorly in trials for melanoma. Day One Biopharmaceuticals got wind of the compound's possible demise and thought it might have promise

for pediatric low-grade glioma. Day One licensed tovorafenib from Takeda, and it was approved by the FDA in 2024. It is marketed as Ojemda.

Lewis-Hall says these examples show that shelved assets can find new life. Discovering, developing, and delivering new medicines is what drugmakers do for a living, she says. "There's the lane that's tried and true that we use every day. But now there's another lane," she says. Instead of putting such drug candidates aside, big pharma should think about putting them in the hands of another organization that could move them forward. "We've learned that it can be done," she says.

Cassidy is more circumspect. He says both serendipity and perseverance at SpringWorks went into developing mirdametinib and nirogacestat, which was approved by the FDA in 2023 and is now marketed as Ogsiveo. "Is that a formula for being able to do this time and time and time again?" he asks. "It's hard to see that, but I think having examples like this out in the world helps, because it does mean that big pharma companies are at least open to the suggestion that their drugs on the shelf might actually be a benefit to patients."

Bakker thought that other big companies would see SpringWorks' success and strive to find homes for their shelved assets. But she's been disappointed. "It's not happening at the speed that I wish," she says. "We still get a lot of lip service from major pharmaceutical companies."

Bakker estimates that hundreds of compounds left on big pharma's shelves could become much-needed drugs, but she acknowledges challenges—such as keeping data organized. SpringWorks had the goodwill from the Pfizer volunteers who used their spare time to pull data together. That's not typical, she says.

"Once an asset is shelved, companies are not really motivated anymore to do anything with it," Bakker says. The people running the project move to another one or leave the company altogether. Data become scattered and incomplete.

There is also the matter of ego, Bakker says. "Somebody with a high-level position has decided that this drug was not valuable enough for the company. That person doesn't want to be wrong."

Samuel Blackman, who cofounded Day One and was the company's head of R&D before leaving at the end of 2024 to become entrepreneur in residence at Google Ventures, wonders if the current economic landscape will make things more difficult for companies trying to revive shelved assets. Noting that the recent successes are tied to firms that started in the 2010s, he says they might simply be a function of that time.

"All of us benefited from buying these drugs for cheap because the sponsors had given up on them," Blackman says. After seeing abandoned assets lead to billion-dollar deals, companies have become reluctant to let go of what they have even if they aren't developing the compounds.

> "There's the lane that's tried and true that we use every day. But now there's another lane."
>
> **Freda Lewis-Hall,** former chief medical officer, Pfizer

What's more, Blackman says, drugmakers are facing pressure to reduce prices at the same time development costs are on the rise. Combine that with funding cuts from the US government—which runs many of the clinical trials for rare diseases—and the economics of developing a scrapped molecule change.

"I think there are some real headwinds here for future plans to take shelved molecules and retarget them, particularly for rare indications," Blackman says. That means that anyone looking to salvage a shelved asset must be strategic about it.

But perhaps the biggest challenge is simply finding the compounds of value.

"You really need some kind of Sherlock Holmes who walks around figuring out which assets are at risk of being shelved," Bakker says.

Speaking during a panel about reviving shelved assets at the BIO International Convention in June, Blackman put it another way: "Pharma buries their dead in private in the backyard." He added that "there is no shelf" when it comes to shelved assets. "There's just a bunch of mounds of dirt in the backyard of big pharma."

When a pharmaceutical company decides to deprioritize a program, the ability to get information about that program comes to an abrupt stop, Blackman tells C&EN. "If you're starting up a new company that's focused on shelved assets, unless you know what you're looking for or you're well connected, it's really hard to find that information."

To that end, a team that includes the CTF's Bakker, Lewis-Hall, and MIT's Lo, is exploring the possibility of setting up a clearinghouse where pharmaceutical companies could list their deprioritized compounds.

"We're trying to get a sense of just how many shelved assets might be out there, how to identify them, and then, ultimately, whether or not we might be able to create some kind of repository that would lower the cost and increase the likelihood for potential drug developers to identify and in-license shelved assets from bigger pharma companies," Lo says. The team expects to publish its findings later this year.

"I don't think we should ignore the ethical dimension of making use of shelved assets," Lo adds, echoing a sentiment expressed by many who spoke with C&EN. These drug candidates have already been tested on people who were willing to undergo experimentation. That means the industry has both an opportunity and a responsibility to make use of them, Lo says. "When you're able to do that by making a lot of money, as Gomekli demonstrated, and help patients along the way, it's a win-win. We can actually do well by doing good." ⬢

Studying bats like the black flying fox (shown) could lead to advancements in human health.

CREDIT: VOLODYMYR DVORNYK/ALAMY

Could bats help us fight the very diseases they give us?

Bats' unique physiology provides ample opportunity—and difficulty

Sarah Braner, C&EN staff

Through their association with vampires, general spookiness, and fighting crime in comic books, bats are often misunderstood and even feared—at least by those who cross Nosferatu and Batman. But recently, they've encountered another public relations problem: bats host many diseases that can spill over into humans, including the viruses responsible for Ebola, SARS, and COVID-19.

Despite hosting so many viruses, the bats themselves resist getting sick. If researchers can find a way to translate this quality to humans, this could grant us more control over our own inflammatory and immunological systems.

Hypotheses vary on just how bats resist illness from viruses, and bat research is far behind immunology research in humans and rodents such as mice. One theory involves bats' unique trait of powered flight. Flight causes a lot of metabolic stress, which manifests through inflammation,

KEY INSIGHTS

- Bats' biology means that these mammals can play host to a lot of different viruses without getting sick.
- Studying how they can do that could have powerful implications for human health, but translating bat findings to human therapies is difficult.
- Researchers in academia and industry are working to surmount these difficulties and bring bat research advances to humans.

and bats seem to be very, very good at managing that inflammation.

A study published in January found evidence that in some species, an extracellular pro-inflammatory protein called ISG15 has a deletion in its genetic code that prevents it from acting as a pro-inflammatory agent inside cells (*Nature*, DOI: 10.1038/s41586-024-08471-0). Bats also display dampened activity of the NLRP3 inflammasome, a protein that, when activated, assembles a complex that promotes inflammation and cell death (*mBio* 2025, DOI: 10.1128/mbio.03204-23).

This inflammation suppression may in turn explain why bats don't get as sick from these viruses. Or at least in part. The theory is that the bat immune systems don't go into hyperactivity, which would damage the bats' own bodies.

John Schoggins, a professor of microbiology at the University of Texas Southwestern Medical Center, says that in theory bats' inflammatory repression could be harnessed for the benefit of humans.

There may be "therapeutic avenues to blunt our own immune responses," he says. "For instance, could you dial down the activity of the NLRP3 inflammasome and make our immune system not so reactive when it's actually trying to combat the virus?" he posits, noting that in cases of severe COVID-19, it's likely that inflammation runs rampant and causes damage.

Bat labs begin

But while research is catching on to bats' appeal, bats are very difficult organisms to work with. Many bat species are endangered, so collecting samples from them in the wild can be tricky.

What's more, while scientists have a wealth of knowledge about how to maintain similar-sized mammals such as mice, far fewer research facilities house a full bat colony for study. Bats are not just flying mice; they have nutritional, environmental, and physical needs that are a far cry from mouse enclosures. (You can order irradiated rodent diets as pellets online; you can't order pellets, even nonirradiated, for bats anywhere.)

Another challenge is that while mice reproduce constantly, many bat species have only a single pup per year. That includes the species that Schoggins's laboratory studies, the black flying fox, which is native to Australia and its surrounding regions. This all makes introducing genetic changes into bats to study the impact of those changes almost impossible, Schoggins says. With what's available to researchers right now, "I think the reality is that we cannot do genetics in bats. There's no genetic model in an in vivo bat system," he adds.

Linfa Wang and his team operate one of the few laboratories with a research colony of cave nectar bats (shown here in the wild).

CREDIT: JON G. FULLER/VWPICS VIA ALAMY

But the field is still advancing, albeit slowly, and pushing the limits of what is possible. Schoggins's lab doesn't have a live bat colony, but the researchers do have tissue samples that they can use for experiments.

"We can study these genes in isolation, and we can do knockouts in the cells and overexpression, and collect good data that really is suggestive of these sort of models, but at the end of the day, we haven't been able to test them in vivo," he says.

Only a few institutions in the world house a bat colony. One of the few is headed by Linfa Wang at Duke–National University of Singapore Medical School, where Wang and his team study the immune systems of cave nectar bats (whose mature females also have only one or two pups per year).

In 2022, the team achieved a first: an in vivo comparison of bats infected with a Pteropine orthoreovirus (PRV) and healthy bats at the single-cell level. The researchers infected adult bats from the colony with PRV, took lung immune cell samples and performed single-cell RNA sequencing, and compared these results with those from samples taken from healthy bats (*Immunity* 2022, DOI: 10.1016/j.immuni.2022.10.008). This is the most precise cell-scale characterization of an immune response in an in vivo bat model.

The Duke–NUS bat colony is a success story, but it took 7 years between the colony's beginning in 2015—with five bats that had been caught from under highway overpasses in Singapore—to the 2022 study's publication. It took even longer than that to even convince people that bats were worth studying.

"I still remember 2007, 2008, I was approaching Peter Doherty, my friend who is a Nobel laureate," Wang says. "I said, 'Peter, I'm convinced that bat immunity has something special. I'm thinking of starting to do bat immunology. You are the expert. Can you help me?' And he said 'No, Linfa, you're suicidal, you know, because for immunologists, if you do any model species outside of a human or a mouse, you will not go far.'"

Wang jokes that this is the first time he's ever ignored a Nobel laureate's advice, and Doherty has since come around to the idea. But he says the hardest part is still getting other people on board the bat train. Journal editors and reviewers are also used to seeing data in mice and humans, Wang says, so they don't often realize that certain experiments or protocols simply cannot be done in bats yet.

"It's always like, 'Oh, it's interesting, but you haven't done this, you haven't done that, why have you done this?' And I say, 'I want to do it, but it's not possible.'"

One way to get around this challenge is to bring bat biology to mice. In 2018, Wang and a team published a paper in *Scientific Reports* detailing the creation of a mouse chimera with bone marrow and spleen cells from bats (*Sci. Rep.* 2018, DOI: 10.1038/s41598-018-22899-1). These "bat-mice," "bat-ized mice," or "batinized mice" still have a role, even though research with bat colonies is now somewhat possible, as they potentially allow researchers to study bat biology without needing the bats themselves. But Wang says they've struggled to gain traction because the chimeras are still difficult to work with, and it's an uphill battle to get funding.

Betting on bats

As research continues to inch forward, one US and Singaporean biotech company, Paratus Sciences, thinks these challenges can be surmounted. The company, which launched in 2023 with Wang as a founding advisor, has a vision to bring bats' many unique qualities—not just their disease resistance but their metabolic and cancer-resistance qualities—to the pharmaceutical landscape.

▲ **A black flying fox hangs out in Australia. Bats' resistance to viral diseases may be linked to their unique trait of powered flight.**

CREDIT: SHUTTERSTOCK

Paratus has spent much of its time creating a huge "data lake," says Mark Cockett, Paratus's chief scientific officer. The company has gathered whole-genome data from 143 bat species and has multitissue transcriptomic data for 50 of them. By comparing bat genomes with mouse and human genomes, researchers can identify differences that could yield therapeutic targets.

Currently, Paratus is developing a potential inflammatory therapeutic based on the bat findings from Wang's research group. The researchers identified a protein called ASC2 as part of another mechanism through which bats may suppress inflammation (*Cell* 2023, DOI: 10.1016/j.cell.2023.03.036).

There are actually two ASC proteins, and bats and humans have genes for both. "The *ASC2* gene in humans is expressed at very, very low levels, if at all," Cockett says. "No one's really worked out what it does. The *ASC2* gene in bats, by contrast, is very highly expressed."

Bat data helped solve the mystery of the role of ASC2. ASC1 helps assemble a pro-inflammatory complex, and ASC2 binds to and inhibits ASC1. Moreover, the bat ASC2 appears to bind to the ASC receptor on the inflammasome much more tightly than its human counterpart can. Thus, Paratus is now trying to find a mechanism to target the inflammasome's receptor, such as an antibody. This approach would be more feasible to develop than mutating human ASC2 to have a higher affinity for human ASC1, as these mutants would risk being recognized as an invader by the person's immune system.

To help speed research along, Paratus has also launched the Bat Biology Foundation, which shares data repositories and provides grants to bat researchers. The foundation helps researchers collect samples from a variety of bat species and sequence them.

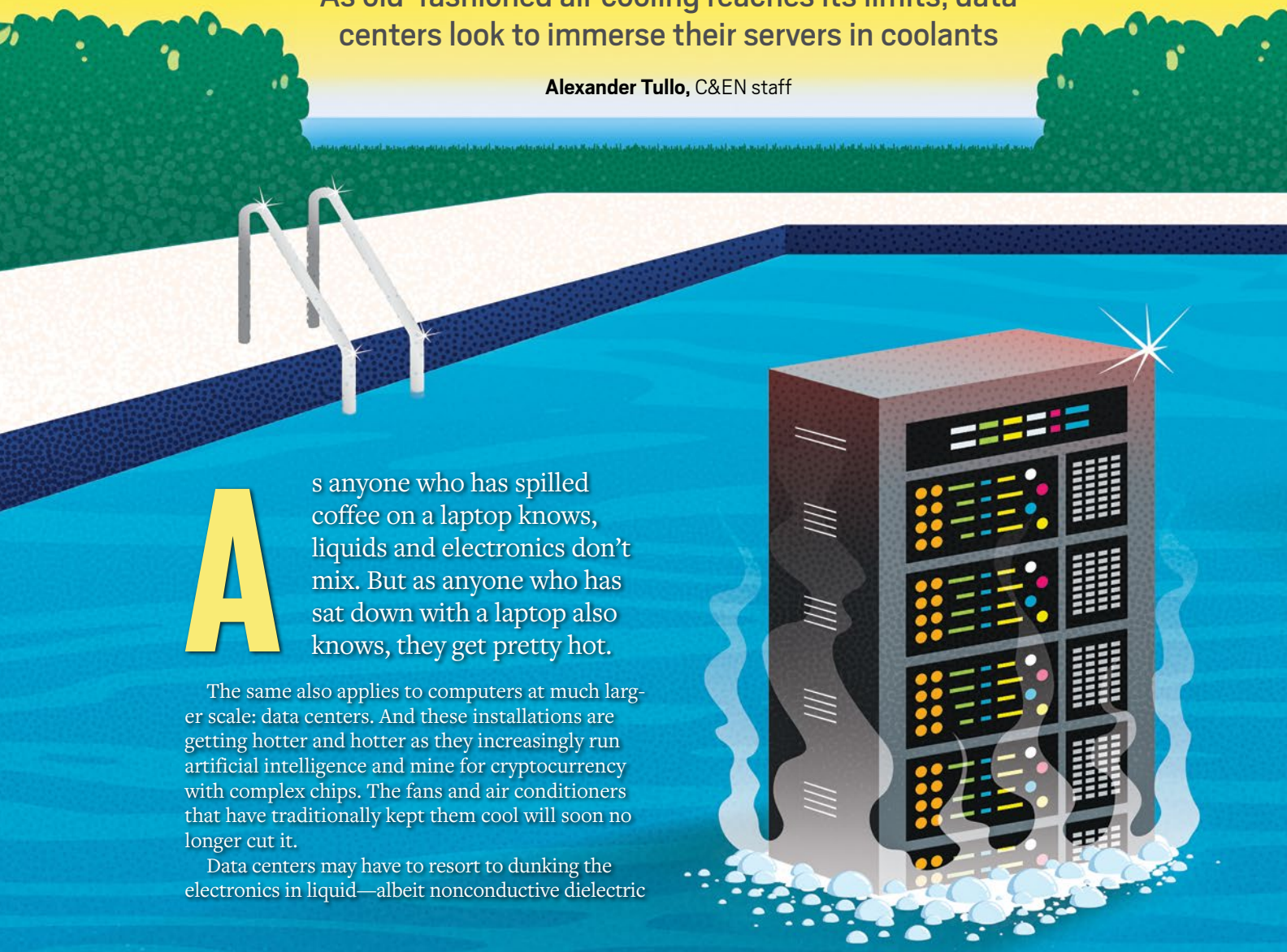
"Early on, I think the academic groups were suspicious of a biotech company, especially in the bat biology world; they had probably never come across a biotech company. So we created a bat foundation that facilitated that initial interaction. I think everyone's over that nervousness of a biotech company now," Cockett says.

Maybe that industry–academia collaboration will give bat research the boost it needs to go mainstream. Or maybe it'll keep a slow burn and remain in relative obscurity until a product is ready. But when, or if, bat research is translatable to humans, bats may finally get some good PR. ⬢

Data centers take the plunge

As old-fashioned air cooling reaches its limits, data centers look to immerse their servers in coolants

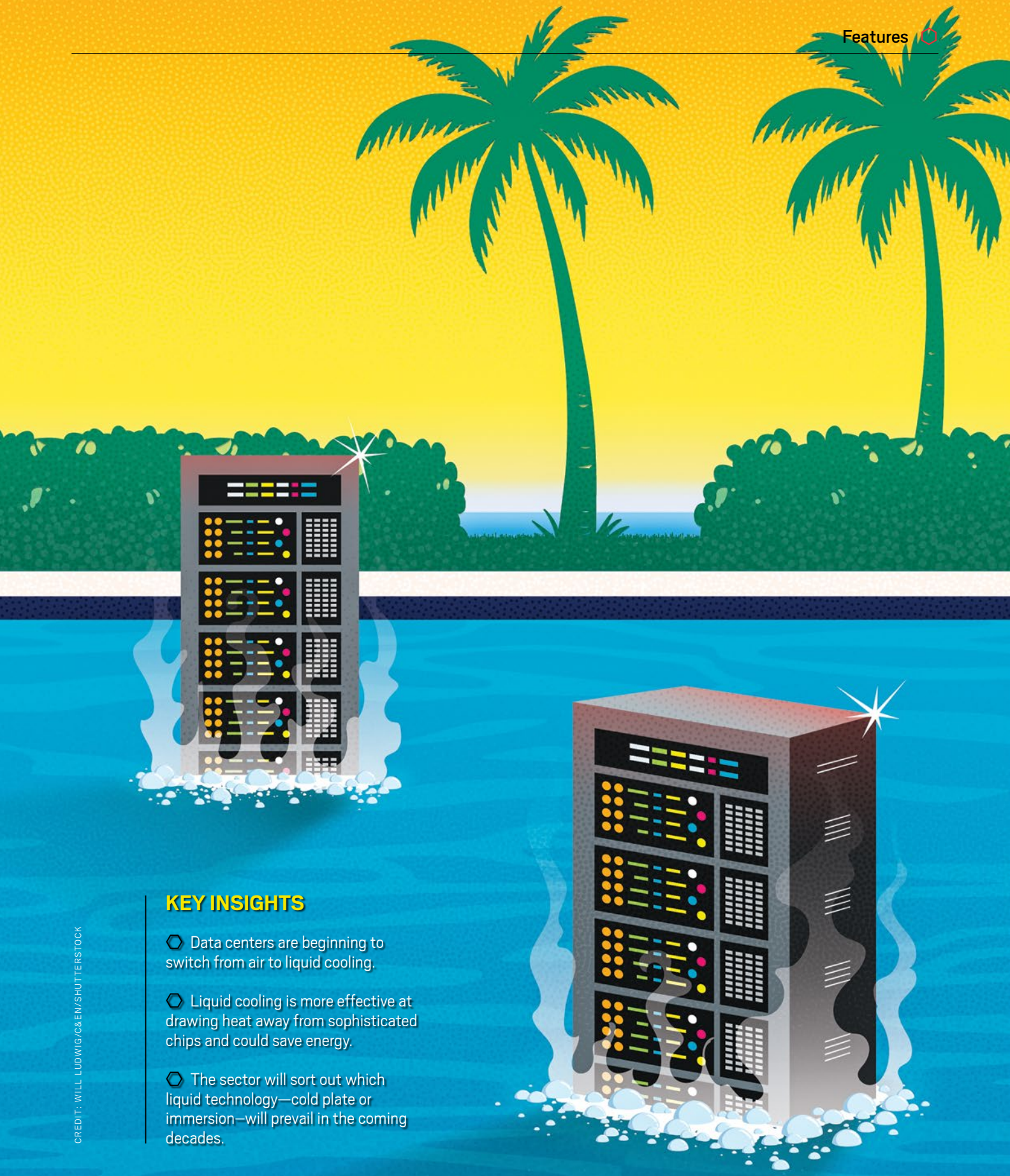
Alexander Tullo, C&EN staff



As anyone who has spilled coffee on a laptop knows, liquids and electronics don't mix. But as anyone who has sat down with a laptop also knows, they get pretty hot.

The same also applies to computers at much larger scale: data centers. And these installations are getting hotter and hotter as they increasingly run artificial intelligence and mine for cryptocurrency with complex chips. The fans and air conditioners that have traditionally kept them cool will soon no longer cut it.

Data centers may have to resort to dunking the electronics in liquid—albeit nonconductive dielectric



KEY INSIGHTS

- Data centers are beginning to switch from air to liquid cooling.
- Liquid cooling is more effective at drawing heat away from sophisticated chips and could save energy.
- The sector will sort out which liquid technology—cold plate or immersion—will prevail in the coming decades.

CREDIT: WILL LUDWIG/C&EN/SHUTTERSTOCK

liquids, which won't harm the electronics but will cool them much better than air can. It will be like the difference on a sweltering day between walking into an air-conditioned building and jumping into a pool.

Liquid cooling is more efficient than air. Up to 40% of the energy consumed by a typical data center goes toward keeping it from overheating. Immersion cooling could reduce that inefficiency and the alarming impact data centers can have on power and water consumption—as well as the greenhouse gases that often go with that electricity consumption.

The concept isn't as exotic as it sounds. Fluids have long been used to manage heat in electric transformers. And back in the 1980s, the Cray-2 supercomputer used a 3M fluorinated coolant called Fluorinert, though the fluid has a high global warming potential and can decompose into toxic products.

A number of chemical makers see a new market. They include ExxonMobil and Shell, which supply hydrocarbon-based fluids; Cargill, which produces biobased liquids; and Chemours, which makes fluorinated refrigerants. They are readying materials to make them suitable for long-term contact with electronics and qualifying them with equipment suppliers. Some already have commercial sales.

The firms face obstacles. Another technology, direct-to-chip cooling, which involves cooled metal plates rather than full immersion, has a head start—and the endorsement of the chip giant Nvidia. But backers of immersion predict that the technology will make solid inroads into the fast-growing market for data center cooling.

"All of these new AI-driven data centers are going to cause massive energy demands," says Francesca Cain-Watson, sales director for Iceotope which is developing immersion cooling systems. "And there's going to be sustainability effects of these AI-driven data centers. So now more than ever, we really need to look to the future of how we're going to liquid cool these data centers."

▲ **In immersion cooling, the circuitry is literally immersed in coolant.**

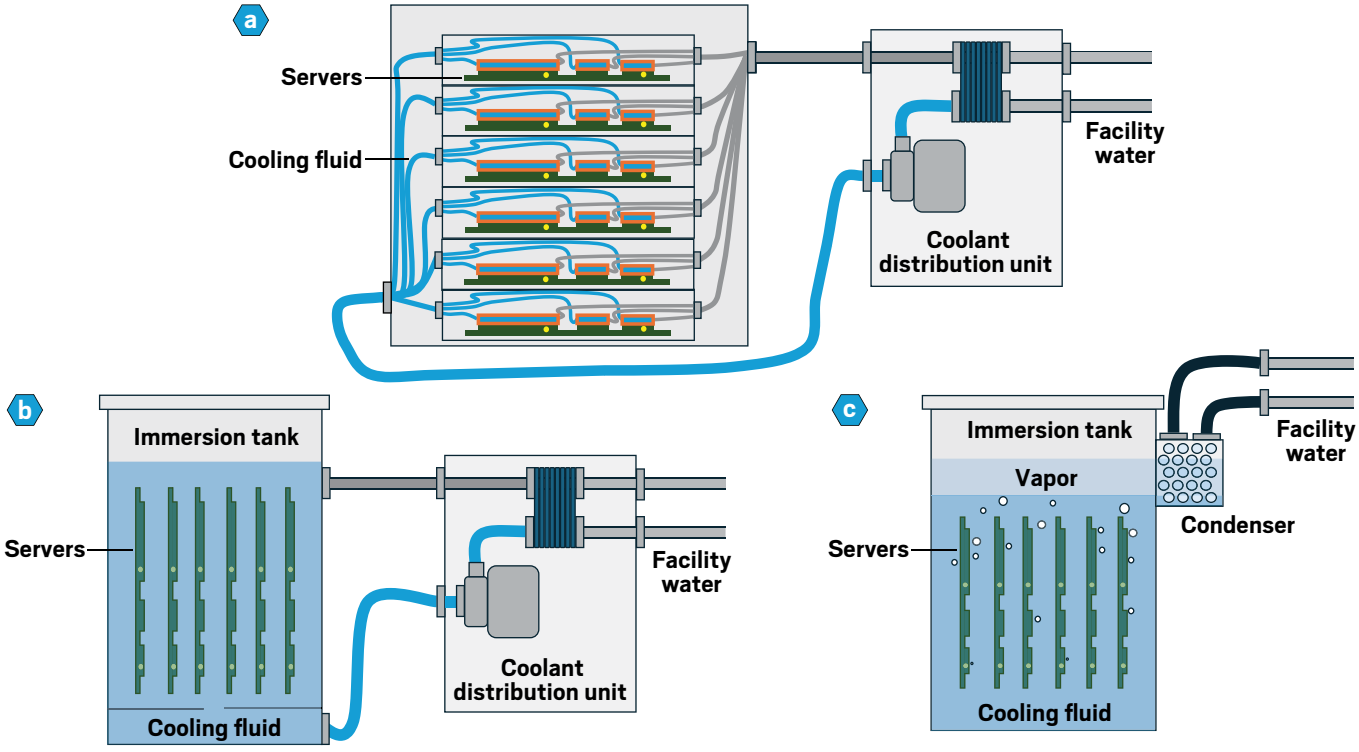
CREDIT: HAL BERGMAN VIA GETTY IMAGES

The end of the line for air

For decades, air cooling has worked well enough in data centers. Fans circulate chilled air through the servers much like they do on our laptops. For more-intensive applications, data centers treat the hot air coming out of the servers with

Three varieties of liquid cooling

In cold plate cooling (a), or direct to chip, a liquid—normally a mixture of water and a glycol—flows through plates that are in contact with computer chips and removes heat. In single-phase immersion cooling (b), the electronics are completely submerged in a circulating dielectric fluid. In two-phase immersion cooling (c), a refrigerant, normally a fluorinated compound, is brought to the boil by the heat the electronics generates. It is compressed and flows back down into the pool of fluid.



chilled-water loops, evaporative water-cooling towers, and even heat exchangers at the rear door of the server cabinet.

But servers for applications like bitcoin mining and AI are running hotter and testing the heat-removal capacity of air. Too much heat can slow chips and even degrade them.

Air cooling systems at data centers are "more or less blowing cold air across the server racks," says Brandon Marshall, global marketing manager for data center cooling at Chemours. The systems use "the same refrigerants that you would see in your home AC," he adds. "We're just reaching that physical limitation of how much heat air can actually capture as it's blowing across a component."

Rack density is a measurement that describes the amount of power flowing through the server rack. Until about 2020, data centers typically ran at 3–10 kW, says Alex Cordovil, a research director at the consulting firm Dell'Oro Group. "A very intense cloud service provider like Google or Meta would be operating at 15–20 kW," he says. AI racks are now reaching 140 kW and more.

According to Green Revolution Cooling (GRC), a company that develops immersion cooling systems, conventional air cooling can handle up to 15 kW per rack. Additions such as rear door heat exchangers take that capacity up to about 70 kW, depending on the specific data center.

As AI server power starts to exceed the cooling capacity of air, data centers are looking to the higher heat capacity of liquids. The technology that operators are mostly opting for so far is direct-to-chip cooling, also known as cold plate cooling. In this system, metal plates are placed over the chips on the motherboard. A coolant, often a mixture of water and propylene glycol or polyethylene glycol, runs through conduits embedded in the plates. The coolant is circulated through a heat removal system and returned to the server. Direct to chip can handle up to 75 kW per rack, according to GRC.

1 phase or 2?

Immersion cooling offers the next tier of performance. It comes in two flavors. More common today is single phase, in which the electronics are

CREDIT: ADAPTED FROM: DOI.ORG/10.1038/S41586-025-08832-3/YANG H. KU/C&EN

immersed in a tank of circulating dielectric fluid, usually hydrocarbons such as poly-α-olefins. The heat from the fluid is rejected via chiller systems and sent back to the tank. This system can accommodate heat of up to 200 kW per rack, GRC says.

Two-phase cooling immerses the circuits in fluorinated refrigerants that have boiling points of around 50 °C. The system takes advantage of the heat of vaporization to absorb heat from the chips faster than single-phase immersion can. The vapor rises and runs through a condenser coil, becomes a liquid again, and returns to the tank. The technology can also handle even-higher heat intensity than single phase.

In addition to keeping high-tech data centers cool, liquid cooling can help operators reduce energy consumption. Every time we upload a picture to Facebook, consult ChatGPT, or Google something, we set electrons into motion at a distant data center, causing real-world work and heat generation. The average Google search requires

> "Crypto has been probably the earliest adopter, the trailblazer in terms of electric cooling."
>
> **—Alex Cordovil,** research director, Dell'Oro Group

0.3 W h of electricity, while that ChatGPT request requires a staggering 2.9 W h, according to a report from the International Energy Agency (IEA).

Goldman Sachs estimates that data centers consume 1–2% of the world's electricity, a figure that could nearly double by the end of the decade. In places building a data center industry, the share is even higher. Data centers already consume about 17% of Ireland's electricity, the IEA says. By 2026, they could consume a third.

Liquid cooling could help. In a paper published in Nature in May, a team from Microsoft and the engineering firm WSP Global assessed the environmental impact of the three liquid cooling technologies against air cooling. Cold plate cooling yields a 15% reduction in energy consumption and a 31% decrease in water consumption. For single-phase immersion cooling, the declines were 15% and 45%, respectively. Two-phase cooling outperforms them both, delivering a 20% decrease in energy use and a 48% drop in water consumption.

Interest in liquid cooling has spiked. "Everybody is trying to figure out how they can incorporate it into their data centers," says Jeff Burke, executive vice president of sales and marketing at GRC. The watershed moment came in March 2024, when Nvidia unveiled its Blackwell series of supercomputing chips. In the announcement, it recommended its own direct-to-chip cooling system.

Annual sales of liquid cooling systems is currently about $2 billion, Cordovil at Dell'Oro says. The firm expects the market to expand to $7 billion by 2030. Direct to chip is the most popular technology so far, with 80–90% of the market.

Heiko Ebermann, global offering manager for liquid cooling at Vertiv, a data center infrastructure company, attributes direct to chip's head start to the hesitation of data center operators to submerge their precious electronics in a liquid. "Reliability of a data center is the number 1, number 2, and number 3 topic. And knowing this, the industry has a bit of caution for huge changes," he says.

Although direct to chip is classified as a liquid cooling technology, it isn't a radical departure from air. The layout of servers remains the same; they just have cold plates and piping in between. Immersion requires putting the electronics in large tanks that resemble supermarket freezers and making changes to the connectors and other components to ensure compatibility with the liquid. Iceotope works around the tank limitation with an immersion system that slides right into the rack.

Immersing the electronics does provide benefits. For example, in immersion cooling, the fluids capture nearly 100% of the heat generated by the circuits, Ebermann says, whereas direct to chip captures only about 80%. That other 20% still needs to be removed with an air cooling system.

Other benefits of single-phase immersion cooling are highlighted by its biggest supporters: cryptocurrency mining operations. "Crypto has been probably the earliest adopter, the trailblazer in terms of immersion cooling," Cordovil says, noting that some mining outfits have been using it for 5–10 years. "They were into immersion cooling when other people were not even thinking much about this technology."

GRC's Burke explains that immersion allows crypto miners to operate at lower temperatures and to "overclock" their chips—make them operate faster than designed. And by providing a more constant temperature than other technologies, immersion eliminates the potential for damaging thermal shock to the circuitry.

In addition to saving energy, eliminating fans improves reliability. "Fans are the number 1 cause of failure in the server," Cain-Watson at Iceotope says.

The liquids themselves also protect the

CREDIT: *STAR TRIBUNE* VIA GETTY IMAGES

▲ **Backers of immersion cooling say it can outperform other methods such as air and direct-to-chip cooling.**

electronics from threats—like dust—posed by the ambient environment, Cain-Watson says. "Having a fully sealed chassis is definitely an advantage."

A chemical opportunity

Chemical firms are lining up to serve the immersion market. And while the use in data centers is cutting edge, the liquids themselves are often simple hydrocarbons repurposed from other applications, such as lubricants and transformer oils.

ExxonMobil launched its line of data center coolants in 2023. The company's formulated coolants are based on poly-α-olefins not unlike those used in synthetic motor oils and in cooling products for military aircraft, electric motors, and large battery installations. "We extended that work and interest into the data center market," says Alistair Westwood, global synthetics marketing manager for ExxonMobil.

The company reformulated the coolants for data centers, lowering the viscosity so that the liquid flows easily and customizing the thermal and dielectric properties. A high flashpoint—in excess of 200 °C in some cases—is necessary for safety. Chemical inertness is also important to prevent the liquid from reacting with the components it is meant to protect.

Shell offers liquids made using its gas-to-liquids technology. The company has long been a supplier of liquids for other electronics applications, including transformers and electric vehicles. Intel recently certified Shell's immersion liquids for use with its fourth- and fifth-generation Xeon processors.

Cargill entered the immersion cooling market in 2022 with its NatureCool fluids. According to Javiera F. McGuiggan, global director of power systems at the agricultural firm, the natural esters—soybean oils that have been treated to remove impurities, acidity, and moisture—are chemically similar to its FR3 fluids, which have been used as transformer oil for more than 30 years.

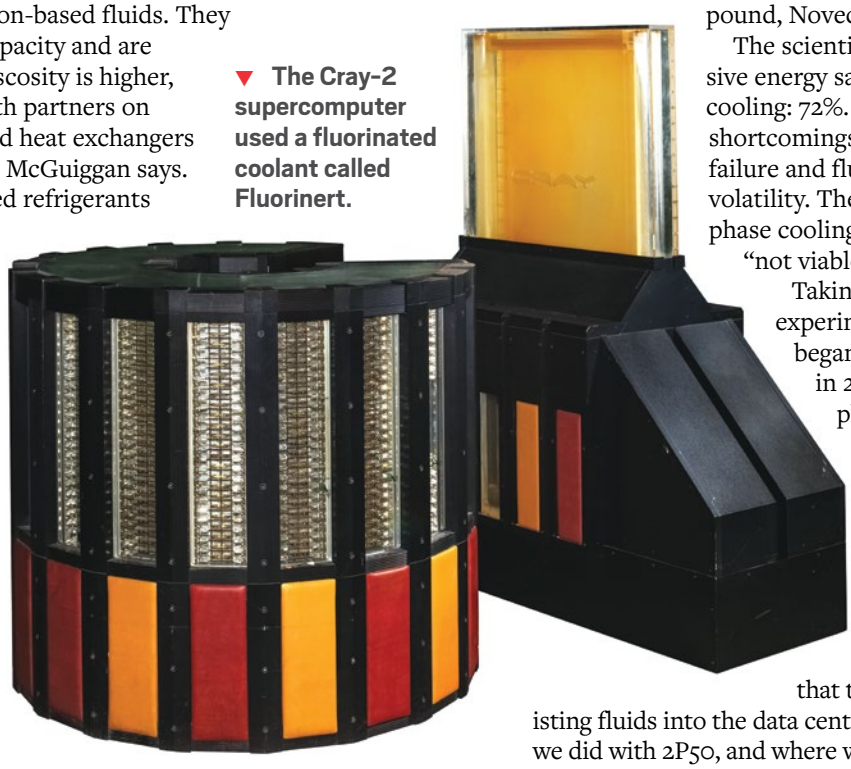
"It is very much vegetable oil that has been refined," she says, noting that the oil is formulated with specialty additives.

The flash point of the esters is inherently higher than that of hydrocarbon-based fluids. They also have a higher heat capacity and are biodegradable. But the viscosity is higher, so Cargill had to work with partners on equipment like pumps and heat exchangers to manage the difference, McGuiggan says.

Producers of fluorinated refrigerants have long provided fluids for the air-conditioning units in air-cooled data centers. Chemours's Marshall sees opportunity in two-phase immersion cooling, especially for data centers that are going to test the limits of other liquid cooling methods.

Using fluorinated coolants for electronics is hardly a new idea, as evidenced by the single-phase system on the Cray-2 supercomputer 40 years ago. And the potential of fluorinated compounds in two-phase systems to quickly draw heat away from electronics has been recognized for more than a decade.

Early attempts yielded mixed results, however.



▼ **The Cray-2 supercomputer used a fluorinated coolant called Fluorinert.**

CREDIT: WIKIPEDIA

In 2016, scientists from Lawrence Berkeley National Laboratory conducted a study on a two-phase immersion cooling system running at the US Naval Research Laboratory. It used a 3M compound, Novec 649.

The scientists reported massive energy savings versus air cooling: 72%. But they also noted shortcomings, such as equipment failure and fluid losses owing to volatility. Their report found two-phase cooling using Novec 649 "not viable at this time."

Taking lessons from this experiment, Chemours began development work in 2019 on a new two-phase immersion cooling fluid that resulted in Opteon 2P50.

Part of the problem with previous efforts in two-phase immersion, Marshall says, was that they shoehorned existing fluids into the data center application. "What we did with 2P50, and where we differentiated, was that this was not an existing molecule," he says.

Opteon 2P50 is a hydrofluoroolefin (HFO) akin to HFO 1234yf, which Chemours forebear DuPont helped develop as a low-global-warming-potential refrigerant for automotive air conditioners. "This

is taking that same base HFO chemistry, and what we did was we developed a molecule that would have attributes that are more applicable to this industry and really submerging the electronics," Marshall says.

One difference is the boiling point. Opteon 2P50 has a boiling point of 50 °C, the temperature at which data center operators aim to keep their servers. Boiling points for HFOs in other applications go as low as -10 °C to -40 °C. As with the single-phase fluids, material compatibility is important. Opteon 2P50 is also a larger molecule than other HFOs, which gives it better insulative properties, Marshall says.

Chemours has been testing Opteon 2P50 with data center operators like NTT Data and DataVolt. "The qualification process for us is going to be the most critical, because that's essentially going to give the green light that says, 'Hey, I can put a server in the fluid,'" Marshall says.

He hopes Chemours's development partners will discover that two-phase systems have advantages over single-phase beyond being able to manage more heat. For example, two-phase systems are passive. The energy needed to circulate the gas comes from the phase change itself, which eliminates the pumps needed in single-phase setups. "We're able to cut that complexity out of the system," Marshall says.

The most common objection to two-phase immersion is that it uses fluorinated fluids. Some operators are wary of chemicals that might be considered per- and polyfluoroalkyl substances (PFAS). The Microsoft paper listed "PFAS fluids used in two-phase immersion face strict regulation proposals" as a "con" for the technology.

In an email to C&EN, Chemours counters, "What constitutes a PFAS is a country by country classification. Regardless of classification, this product is safe for the intended use for which it was developed—in sealed, closed-loop two-phase immersion cooling systems using materials manufactured under the highest standards." And similar refrigerants are already widely used in cars and other applications.

Another hurdle is that two-phase immersion is even more of a detour for data centers from air or direct to chip than single phase is. "That different architecture on the two-phase immersion, at least in our view, is why the immediate adoption within data centers will be around some sort of direct to chip before some sort of immersion," says Jeff Dormo, president of sustainability and decarbonization at Honeywell.

Honeywell competes with Chemours in HFOs, but Dormo says the company is focused on using its refrigerants in direct-to-chip applications, including two-phase direct to chip. That technology would replace the water and glycol used in conventional direct to chip with HFOs that would undergo a phase change to absorb heat faster. Two-phase immersion is a longer-term prospect. "We'll continue to stay flexible," Dormo says.

Cordovil at Dell'Oro agrees that two-phase direct to chip is likely to penetrate the market before immersion. But in the future, he adds, "it is very possible that two-phase immersion might start becoming a necessity."

The market is growing so fast and the technology is advancing so rapidly that Cargill's McGuigan isn't concerned about competition between different cooling technologies. "Everyone's going to get a piece of that pie," she says. "I'm not dramatically worried that there will be room for immersion. There'll be room for air cooling. There'll be room for direct to chip still." ⬢

Pollution

A new role for chemists: Tackling toxic air in conflict zones

As modern warfare weaponizes the very air we breathe, chemists should leverage their skills and knowledge to detect, neutralize, and reclaim toxic atmospheres in the world's most devastated conflict zones

Karen J. Cloete, special to C&EN

Armed conflict doesn't just destroy lives—it chemically alters the environment in ways we've barely begun to measure. War zones become unregulated chemical reactors: Burning fuel depots, pulverized infrastructure, shattered electronics, and scorched forests release a torrent of pollutants into the atmosphere.

Each conflict etches its own toxic fingerprint: fine particulate matter of 2.5 µm in diameter or smaller ($PM_{2.5}$), black carbon, sulfur dioxide, dioxins, polycyclic aromatic hydrocarbons, heavy metals, microplastics, asbestos, and radionuclides, all interacting in unstable, synergistic ways that amplify harm across time and borders. These contaminants linger in lungs, rewire immune systems, and seed chronic illnesses in populations who have often lost everything else.

▲ **Smoke and flames at the Greater Burgan oil field in Kuwait in March 1991. Chemists can help address the environmental consequences of conflicts like the 1991 Gulf War.**

CREDIT: ASSOCIATED PRESS

The inhalable aftermath of modern warfare

While humanitarian relief often focuses on trauma, malnutrition, and displacement, one question remains dangerously overlooked: What are people breathing? In Syria, deteriorating air quality led to a surge in respiratory illnesses

amid the rubble. In Ukraine, war-driven wildfires have released nearly 163 million metric tons of emissions. In Gaza, bombed-out industrial zones emit plumes dense with unmonitored toxins—pollution that travels far beyond borders, ignoring ceasefires and peace treaties.

This pattern is not new. In the Vietnam War, the US military deployed over 71 million liters of herbicides like Agent Orange, contaminating soil and water with dioxins that still affect generations through birth defects and cancers. During the 1991 Gulf War, the deliberate ignition of more than 600 Kuwaiti oil wells released massive clouds of black smoke laden with sulfur dioxide, polycyclic aromatic hydrocarbons, and heavy metals, darkening skies and sickening both soldiers and civilians. In Kosovo and the other Balkan States, depleted uranium munitions left toxic residues in bombed areas, raising concerns over long-term soil and water contamination. These examples underscore a critical truth: War doesn't just kill; it chemically reshapes ecosystems and endangers public health for decades.

Chemistry must be at the negotiating table

It is no longer enough for chemistry to be reactive in terms of crisis response—designing drugs, building detectors, and analyzing samples of post-exposure contaminants. Chemistry must now be *proactive*: anticipating, mitigating, and transforming the airborne consequences of war. We must embed chemists in humanitarian logistics, reconstruction protocols, and peacekeeping missions—not as technical advisers but as core architects of post-conflict resilience.

This new role—from laboratory-bound specialist to field-based architect of recovery—demands a radical reimagining of the field. Chemists should be doing the following:

- Developing rugged, autonomous air-monitoring systems deployable in war zones, refugee camps, and reconstruction sites.
- Engineering biomaterials such as drone-deployable moss walls that passively filter $PM_{2.5}$, volatile organic compounds, and heavy metals in real time, offering low-maintenance, electricity-free air purification in extreme conditions. Delivered as lightweight, modular kits, these walls can be air-dropped or positioned by drones onto rubble, scaffolding, or tents in refugee camps, field hospitals, and bombed-out urban zones.
- Designing wearables that track individual exposure to toxins, enabling both medical triage and epidemiological research.
- Participating in diplomatic efforts to standardize international air-quality protocols for conflict zones.

A new code of ethics for the chemical sciences

What if the air itself became a domain of peacekeeping? What if chemists were trained not only in synthesis and analysis but in diplomacy, justice, and disaster ethics?

The American Chemical Society and allied institutions must recognize that clean air in conflict zones is not just a health issue; it is a chemical and geopolitical imperative. This means investing in the following:

- Transdisciplinary task forces that pair chemists with diplomats, public health experts, and peace builders
- Interdisciplinary research grants focused on the longitudinal health effects of conflict-specific pollutants, particularly among children and pregnant women
- Advocacy for global air-disarmament frameworks that treat certain forms of chemical pollution as violations of humanitarian law
- Global partnerships that design air-quality monitoring systems tailored to conflict environments
- Working groups to develop guidelines on chemical safety and environmental remediation in unstable regions
- Training for the next generation of chemists to operate at the intersection of environmental justice, security, and humanitarian science

Financing peace through chemistry

We need not only science but systems. International environmental health bonds, supported by multilateral institutions and governed by transparent accountability frameworks, could finance air monitoring, mobile clinics, and real-time data platforms in post-conflict regions. While environmental health bonds are still an emerging concept, similar mechanisms do exist: for example, the World Bank Group's Pandemic Emergency Financing Facility and the International Finance Facility for Immunisation have successfully used bond structures to mobilize funds for global health crises.

These models demonstrate how impact-linked financing can be adapted to address airborne toxic exposure in conflict-affected areas. For example, a dedicated global clean-air fund for conflict zones could support scalable innovations—just as the Green Climate Fund catalyzed climate-resilience technologies.

The future is already in the air

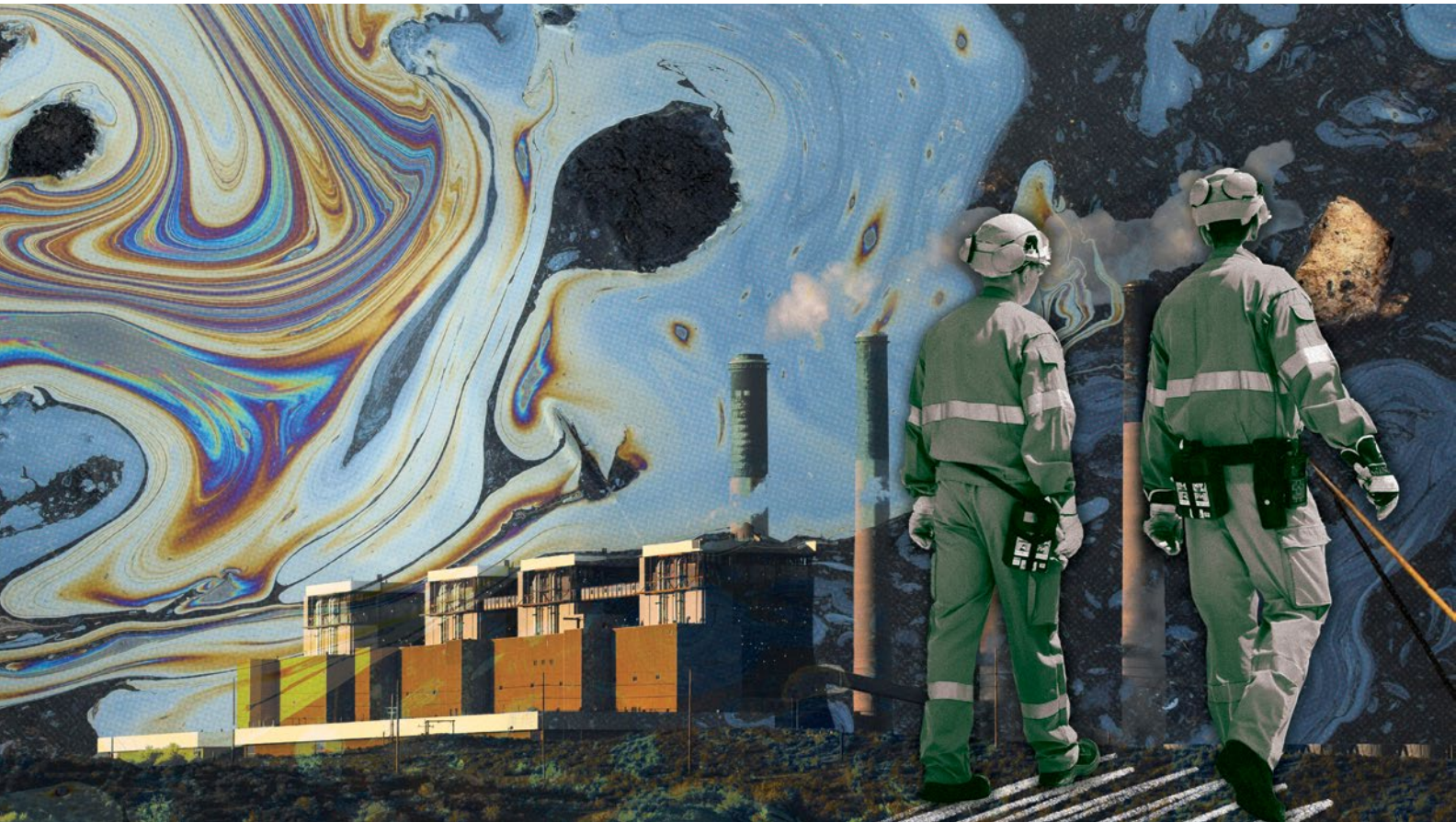
Clean air must be recognized as a nonnegotiable human right—even in war. Chemists must become the sentinels of that right, defending it not only with data but with design, diplomacy, and an unshakable commitment to scientific and humanitarian responsibility.

Today's battlefield is not only on land or in cyberspace—it is in the atmosphere itself. The question is, Will chemistry be ready?

Karen J. Cloete is a senior scientist at the University of South Africa specializing in nanotechnology, environmental science, accelerator-based analysis, and the intersection of chemistry and global governance.

Views expressed are those of the author and not necessarily those of C&EN or ACS.

Do you have a story you want to share with the chemistry community? Send a submission of about 800 words to cenopinion@acs.org.



Column

New panel confirms importance of fighting pollution

After years of discussions, 107 nations agree to establish the Intergovernmental Science-Policy Panel on Chemicals, Waste and Pollution

Tom Welton, special to C&EN

On Friday, June 20, 2025, in the Uruguayan seaside city of Punta del Este, governments from across the world agreed to establish the Intergovernmental Science-Policy Panel on Chemicals, Waste and Pollution (ISPCWP). This was the result of over three years of negotiations that were initiated by a resolution of the United Nations Environment Assembly in the spring of 2022, which years of work went into developing.

This may sound like a case of one committee deciding to form another committee, but it's truly a globally significant event.

Readers are likely familiar with the Intergovernmental Panel on Climate Change (IPCC) and perhaps with the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES). Those two bodies are tasked with providing the best available science to enable sound, evidence-based policymaking. So is the new ISPCWP.

The very existence of such a body will have

An ongoing series written by a rotating group of contributors.

CREDIT: MADELINE MONROE/C&EN/SHUTTERSTOCK

an effect immediately. I am imagining a meeting of a country's new minister or secretary for the environment with their senior civil servants. Up to now, this high-level official, who may not have any science background, would have been told about the IPCC and IPBES and so would have recognized the need to address the important global issues those bodies work on. Now the official will also be told about the ISPCWP. That means the global significance of chemicals, waste, and pollution, critical issues for chemists and the public, will be elevated on the political agenda. The impact of this change should not be underestimated.

Making the best possible science available and accessible to policymakers around the world is likely to be uncontroversial to anyone reading this. It's also likely that you think pollution and its impacts are a major global concern. Just as I have been writing this, a new study has been published in *Nature* on concentrations of nanoplastics in the North Atlantic. We are a long way from the ideas of my youth, when we basically believed that the Earth was an infinite sink for our waste.

> The purpose of the ISPCWP is to inform policy, not to dictate it.

Other multilateral environmental agreements (MEAs) exist to deal with issues covered by the ISPCWP, named after cities such as Montreal, Basel, Rotterdam, Stockholm, and Minamata, but the new panel is not intended to duplicate the work of these MEAs. Each of these MEAs has a specific and tightly defined remit. Unfortunately, many environmental problems fall outside these silos or across more than one of them. The ISPCWP will be able to look at these broader environmental issues. Beyond these issues, currently unknown problems will be discovered in the future, and because of this, horizon scanning is baked into the language of the new agreement. Finally, the panel is committed to capacity building, although it's unclear whether this means building the capacity of individuals and states to take part in the ISPCWP or something much broader.

Historically, we assumed that human activities would not have global impacts, but the discovery of the ozone holes and climate change turned this notion on its head. We can't go on with a model of pollute first and worry about it later. The ISPCWP must address how we can have the amazing benefits that chemical products bring to our lives without causing irreparable damage to human health and the environment.

That said, the purpose of the ISPCWP is to inform policy, not to dictate it. And policy is not synonymous with regulation. Although regulation is important, the ISPCWP must also address how policy can encourage positive innovation for environmentally beneficial solutions.

In its next meeting, the panel will settle on its initial priorities. This exciting prospect could lead the world to take the first steps toward implementing solutions to some of the many issues within the panel's purview.

The ISPCWP is an intergovernmental panel, so its governing body will be made up of government representatives. Below this will be the Interdisciplinary Expert Committee (IEC), which will do the work of commissioning and receiving the outputs of the ISPCWP, and groups will be put together to produce those outputs. Opportunities exist for chemical scientists and engineers to be involved in all these efforts and not just to make technical contributions to reports.

If the ISPCWP is to be successful, it must rely on both the best available science and the best scientists. These contributions need to come from all parts of the chemistry enterprise, industry as well as academia, chemical and materials innovation as well as environmental sciences. Could this be you? Engagement with the ISPCWP will be unremunerated, but what could be a better gift to the world than your time and expertise?

CREDIT: COURTESY OF TOM WELTON

Professor Tom Welton, OBE, is an emeritus professor of sustainable chemistry at Imperial College London and past president of the Royal Society of Chemistry. In 2004 he became the world's first (at least as far as he knows) professor of sustainable chemistry. As the RSC's ambassador for sustainable chemical policy, he has been participating in the process to establish the ISPCWP through the Scientific and Technological Community Major Group of the United Nations Environment Programme.

Views expressed are those of the author and not necessarily those of C&EN or the American Chemical Society.

Comment

Amplifying initiatives aligned with the ACS core values

Mary Carroll, ACS immediate past president

The American Chemical Society commitment is to improve all lives through the transforming power of chemistry. During my time in the ACS presidential succession, I focused on amplifying ACS initiatives: promoting activities that yield maximum results for members and society and working within existing ACS structures to effect positive change. Here, I emphasize recent and ongoing ACS initiatives that align with the core values articulated in the ACS Strategic Plan.

> Chemistry drives scientific discovery and innovation.

Passion for science: We believe chemistry drives scientific discovery and innovation.

- ACS actively advocates for chemistry and its practitioners. As Carolyn Ribes, chair of PAPR, points out, "Now is the time for chemists to speak up and be heard." In June, during a legislative fly-in, the ACS Board of Directors held an event with the bipartisan Congressional Chemistry Caucus and visited offices on Capitol Hill to advocate for sustained, significant federal funding for science. Consider joining the Act4Chemistry Legislative Action Network and making use of its resources, which include a toolkit with advocacy handouts for US lawmakers that emphasize science's contributions to each state's workforce and economy.
- Scientific discovery and innovation originating from industry, government, and academia will be showcased at ACS Fall 2025 in Washington, DC. The meeting will feature Kavli Lecture Series keynotes by Sahika Inal and Sir Cato T. Laurencin, hot-topic programming by the ACS Committee on Science, the C&EN Talented 12 symposium, a wide variety of timely symposia organized by ACS divisions, and the 2025 Heroes of Chemistry awards.

Lifelong learning: We promote equitable access to science education, resources, and career pathways.

- ACS chief operating officer LaTrease Garrison has announced that ACS is establishing a new undergraduate scholarship program, with the application submission period to open later this year.
- "Building Chemistry Careers Inclusively" is a major theme of 2025 ACS president Dorothy Phillips's presidency. She's championing the ACS strategic initiative on fostering a skilled technical workforce and recently emphasized the long-standing ACS commitment to providing learning resources for everyone.

Inclusion and belonging: We create environments where people from diverse backgrounds, cultures, perspectives, and experiences thrive.

- The ACS Fall 2025 Digital Meeting includes a wide variety of Global Virtual Symposia, held at times convenient for presenters around the globe.
- The Committee on Committees (ConC) has petitioned the ACS Council to establish the Committee on the Advancement of LGBTQ+ Chemists (CALC) in order to support and recognize LGBTQ+ chemistry professionals and their allies. This recommendation came out of a recent external review and subsequent ConC discussions of the future of ACS committees.
- The council will also consider a petition from the Committee on Local Section Activities that specifies additions to the territory of 82 local sections to ensure that all members residing within the US are assigned to a local section.

Sustainability: We embody safe, ethical, and responsible practices.

- ACS is a recognized leader in promoting sustainability. At the 29th Green Chemistry & Engineering Conference, ACS president Dorothy Phillips signed the Stockholm Declaration on Chemistry for the Future on behalf of ACS as a society. Individuals can also sign, and I encourage ACS members to consider joining me in doing so.
- The 11th edition of the ACS Professional Employment Guidelines, drafted by the Committee on Economic and Professional Affairs, is up for action by the council. This document covers a range of employment practices and is geared toward professional scientists and their employers.

The initiatives highlighted above are just a sampling of the many ongoing activities that demonstrate our collective commitment to the core values of ACS. I encourage all members to find ways to contribute to the ACS mission: Advance scientific knowledge, empower a global community, and champion scientific integrity.

More online

Read the full Comment online.

Views expressed are those of the author and not necessarily those of C&EN or ACS.

CHRISTINE BRENNAN SCHMIDT

Comment

Financial expertise requires committee evolution

Natalie LaFranzo, director–at–large, ACS Board of Directors

With the approval of a revitalized strategic plan in 2024, the American Chemical Society Board of Directors began an exercise in self-reflection. Part of this effort, which has continued in earnest in 2025, relates to the board committee structure, which is critical to fulfilling our fiduciary responsibility effectively. The ACS Board is similar to ACS governance, which relies on a robust committee structure to achieve its goals. For some work, there is alignment between board and society committees. An example is the Committee on Chemistry and Public Affairs, a society committee, and the Committee on Public Affairs and Public Relations, a board committee. The work done by both committees is in service of elevating the reputation of science, but how each accomplishes this goal is different.

> The ACS Board is similar to ACS governance, which relies on a robust committee structure to achieve its goals.

The board committee review has highlighted opportunities for removing redundancy in our structure, as well as identifying gaps in our proficiency or resourcing. In my Comment dated April 29, 2025, I shared reflections about the state of ACS's financial resources and performance, and how they've evolved over time. I alluded to the idea that the board and the Committee on Budget and Finance (B&F) had been thinking about how we can ensure strong financial stewardship and the expertise we'll need to do so. Since then, B&F leadership, the board of directors, the Committee on Committees (ConC), and our executive leadership team have worked together to redefine what the society needs and the right structure to accomplish this. In the coming months, we'll share more details about the proposed path forward, which I've summarized at a high level below:

Step 1: Establish a board finance committee

The board seeks professional financial expertise to enable management of our financial assets and risks and will establish a new board finance committee. By establishing a finance committee, we can bring in public accountants, financial analysts, merger and acquisition experts, and other advisers as needed to navigate enterprise-level decision-making. While these types of experts may exist within our membership (and we'd be thrilled to connect with them), this new structure will enable us to recruit mission-driven professionals who, while not chemists by training, are willing to volunteer their time and energy toward helping us achieve our vision. It will also represent a smaller group (likely no more than seven members, with two to four of the members being governance leaders) who can nimbly respond to current events or react to time-sensitive business opportunities as they arise. Once established, this group is well positioned to manage the annual budget and enterprise-level financial goals.

Step 2: Realign B&F to focus on governance finances

With financial experts managing the high-level annual performance of our assets, B&F will have the time and energy to focus on engaging more closely with our governance structure and supporting strategic deployment of our resources. Our cross-functional team of leaders have aligned on four focus areas for the committee:

1. Support component groups and their leaders.
2. Strategically advance programs, products, and services that benefit members.
3. Establish multichannel communications.
4. Retain financial impact assessments.

Step 3: Reflect and realign as needed

An important part of this evolution, and our operations in general, is that it should not reflect a finite, locked state but a step toward something better. We should be routinely reflecting on whether or not our governance structure at all levels is serving us. Through ConC's committee review process, we'll be able to learn whether the new role of B&F is effective and rewarding, and what changes we might need to implement in the future.More broadly, the ACS Board is always eager to hear your feedback on what's working, what's not, and how we can leverage resources to empower our members to improve all lives through the transforming power of chemistry.

Have something important to share? You can reach us at secretary@acs.org.

Views expressed are those of the author and not necessarily those of C&EN or ACS.

More online

Read the full Comment online.

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Volunteer Voices

Mohammad N. Siddiqui chats about chairing an international chapter

The professor of chemistry shares his experience as an ACS member in Saudi Arabia

Nina Notman, special to C&EN

Mohammad N. Siddiqui is a professor of chemistry at King Fahd University of Petroleum and Minerals in Dhahran, Saudi Arabia. "I teach undergraduate and graduate-level chemistry courses and lead extensive applied and industrial chemistry research initiatives," he says. His research focuses include fuel desulfurization, chemical recycling of waste plastics, and designing degradable polymers.

Siddiqui joined the American Chemical Society and its Saudi Arabia International Chemical Sciences Chapter in 1995 and started volunteering with the chapter about 5 years later. He has been the chair of the Saudi chapter since January 2025. He also held this role in 2006 and 2017.

The Saudi chapter, formed in 1993, was the first ACS

A look at the stars that make ACS invaluable

VITALS

- **Current location:** Dhahran, Saudi Arabia
- **Current job title:** Professor of chemistry, King Fahd University of Petroleum and Minerals
- **Key volunteer role:** Chair, ACS Saudi Arabia International Chemical Sciences Chapter
- **Favorite element:** Nitrogen

CREDIT: COURTESY OF MOHAMMAD N. SIDDIQUI

international chapter. Today, it has more than 300 members, and approximately 200 other local scientists benefit from its activities. Thirty additional ACS professional international chapters have now been established across Africa, the Middle East, the Asia-Pacific region, Europe, and South America.

Siddiqui recently spoke to Nina Notman about being an international chapter chair and organizing the first international ACS conference in Saudi Arabia. This interview was edited for length and clarity.

What activities does the Saudi chapter offer its members?

It hosts technical dinner meetings with presentations and panel discussions in collaboration with other professional societies, including the Chemicals Research and Innovation Society. It organizes visits to in-kingdom and out-of-kingdom industry and research and development centers. It offers specialized short courses on analytical instrumentation and on high school teaching skills. Additionally, chapter members mentor members of the ACS international student chapter at King Fahd University of Petroleum and Minerals.

Why did you join the Saudi chapter?

I was drawn to the monthly technical dinner meetings as they provided an excellent platform for me to learn from experts and network with key stakeholders in the Saudi scientific and industrial community. Volunteering also gives me moral and emotional satisfaction from contributing, even in small ways, to building a better society. Everyone should come forward to help create a better future.

What does being the Saudi chapter chair involve?

The chair's responsibilities include, but are not limited to, overseeing all the chapter's activities, exploring the possibility of cooperation with other societies, working with the board of directors to promote the chapter, and representing the chapter at public events and conferences. I will represent the society at Labtech2025 in Jazan in November.

> Volunteering also gives me moral and emotional satisfaction from contributing, even in small ways, to building a better society. Everyone should come forward to help create a better future.

Mohammad N. Siddiqui, chair, ACS Saudi Arabia International Chemical Sciences Chapter

Please tell me about the global conference that the Saudi chapter is hosting this year?

The chapter is organizing its first international conference located in Saudi Arabia. It has organized numerous international conferences before—but these were held in Bahrain because Saudi Arabia was not open at that time. The conference is titled: Saudi Chapter of the American Chemical Society International Conference 2025. Its theme is "Chemical Innovations for Sustainable Future Industries" and it will bring together regional, national, and international experts in all aspects of chemistry. It will be held at King Fahd University of Petroleum and Minerals on Nov. 11–13.

What benefits does your chapter gain from being affiliated with ACS?

Being a member of an international society provides a wider platform and access to more resources than joining a local society. Our activities map with those of ACS. We have a very strong relationship with the international office. We participate in their awards programs. An ACS president, past president, or president-elect has participated in all our Chemindix, Labtech, and other international conferences. ACS also connects us with additional keynote speakers and advertises our meetings on its portal.

Awards

ACS names 2025 fellows

36 new fellows are honored for their contributions to science

Sara Cottle, C&EN staff

The American Chemical Society has named 36 members as new ACS fellows for 2025. ACS fellows are ACS members who have shown outstanding achievements in and contributions to science, the chemistry profession, and the society. These fellows will be celebrated at a ceremony held during ACS Fall 2025 in Washington, DC.

Nominations for the 2026 class of ACS fellows will open in early 2026. Information about the program, including a list of previously named fellows, is available at www.acs.org/fellows.

The names and affiliations of the 2025 ACS fellows are as follows:

Frances Arnold
California Institute of Technology
Louise A. Berben
University of California, Davis
Christopher Bowman
University of Colorado
Chieh-Min Cheng
Polaroid
Alexei Demchenko
Saint Louis University
Kirby B. Drake
Kirby Drake Law
Stephen J. Eichhorn
University of Bristol
James T. Fletcher
Creighton University
Marilyn D. Gorman
North Brunswick Township High School (retired)
Paul J. Hergenrother
University of Illinois Urbana-Champaign
Liangbing Hu
Yale University
Anastasia Ilgen
Sandia National Laboratories
Feng Jiao
Washington University in St. Louis
Pamela K. Kerrigan
University of Mount Saint Vincent
Jerry Wayne King
University of Arkansas (retired)
Mary Beth C. Koza
North Carolina State University
Thomas Lectka
Johns Hopkins University
Lin Shu Liu
United States Department of Agriculture
Katherine N. Maloney
Point Loma Nazarene University
Richard T. Mayes
Oak Ridge National Laboratory
Dhriti Nepal
Air Force Research Laboratory
Karen W. Phinney
National Institute of Standards and Technology
Jeffrey Rack
University of New Mexico
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Dow
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Cargill
William Frederich Schneider
University of Notre Dame
Andrew Scholte
Sanofi
Jana Shen
University of Maryland School of Pharmacy
Linda Shimizu
University of South Carolina
Michael Stephen Silverstein
Technion
Pete M. Smith
Westminster College
Brent Sumerlin
University of Florida
Gloria Thomas-Fuller
Southern University and Agricultural and Mechanical College
Davita L. Watkins
Ohio State University

How to get helpful help

We all get by with a little help from our friends. But in professional settings, we don't always feel like we can ask for help. Asking for help is not admitting failure, but rather using your resources to ensure that expectations are met. Knowing how to ask for help ensures that you get help that is actually useful, or even crucial, in meeting your goals.

Permanent or temporary? First, determine how much and what kind of help you need. Do you need someone to take a brief look at an article and provide copyediting, or do you need them to look at a first draft and determine if the direction and scope are appropriate for the publication venue? Do you need direction on how to proceed, someone to teach you an unfamiliar procedure, or do you need a new full-time person assigned to help you? Do you need someone else to learn one of your tasks so they can back you up in case of emergency?

Make the ask clear. Once you know what you need, identify the individual who has the best chance of providing it. Write down the problem, what you have tried, and exactly what and when you need that person to do, so you can make a clear ask. Carefully select the time and method of communication for the ask. The more help you need, the more personal the method you should choose (email, text, IM, phone call, in-person). Always be polite, and make sure the other person can say "no"—much better if they tell you they are not able to help, rather than say they will but then not meet your needs. The clearer you can make the "ask," the more likely you will be to get what you need.

Clarify your understanding. Often, verbalizing the issues to another person can help you clarify them in your own mind. Verify their understanding of what you need, their expertise and ability to do what you need, and their willingness to do it by your deadline. Use a collaborative approach, enlisting their help and expertise to solve your problem.

Set realistic expectations (including accountability). Even if they agree to help, the other person may not actually follow through, or they may not do so in a timely manner. If you depend on them completely and stop looking for other ways to solve the problem, you could be in trouble if this happens. Decide if it's worth getting your—or their—supervisor involved to help them change their priorities to include your issue.

Be grateful. If someone does help, make sure they know their efforts are appreciated. Provide feedback on which of their strengths specifically were useful, and if appropriate, make their supervisor aware of their contribution to the success of the project. Be ready to help others yourself, and wherever possible, get some goodwill in advance by helping others before you need to ask them for help.

Asking for help is not a sign of weakness; it is knowing your limits and meeting your responsibilities. Obtaining help may have additional benefits, such as strengthening your relationships with your coworkers, highlighting flaws in existing workflows, and improving workflows overall.

Get involved in the discussion. The ACS Career Tips column is published monthly in C&EN. Send your comments and ideas for topics for future columns to careernavigator@acs.org.

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WAcKY ReAcTiONS

This is the first of C&EN's new monthly crosswords, put together by a small team of experienced crossword constructors. This month's puzzle was assembled by Daniel Bodily, a robotics engineer at 3M in Minnesota, and George Barany, professor emeritus of chemistry at the University of Minnesota Twin Cities. They thank Marcia Lysakowski Brott and Irene Cesa for helpful advice. C&EN thinks that this crossword, whose theme should become clear to the chemistry-minded, has many of the elements of a great puzzle.

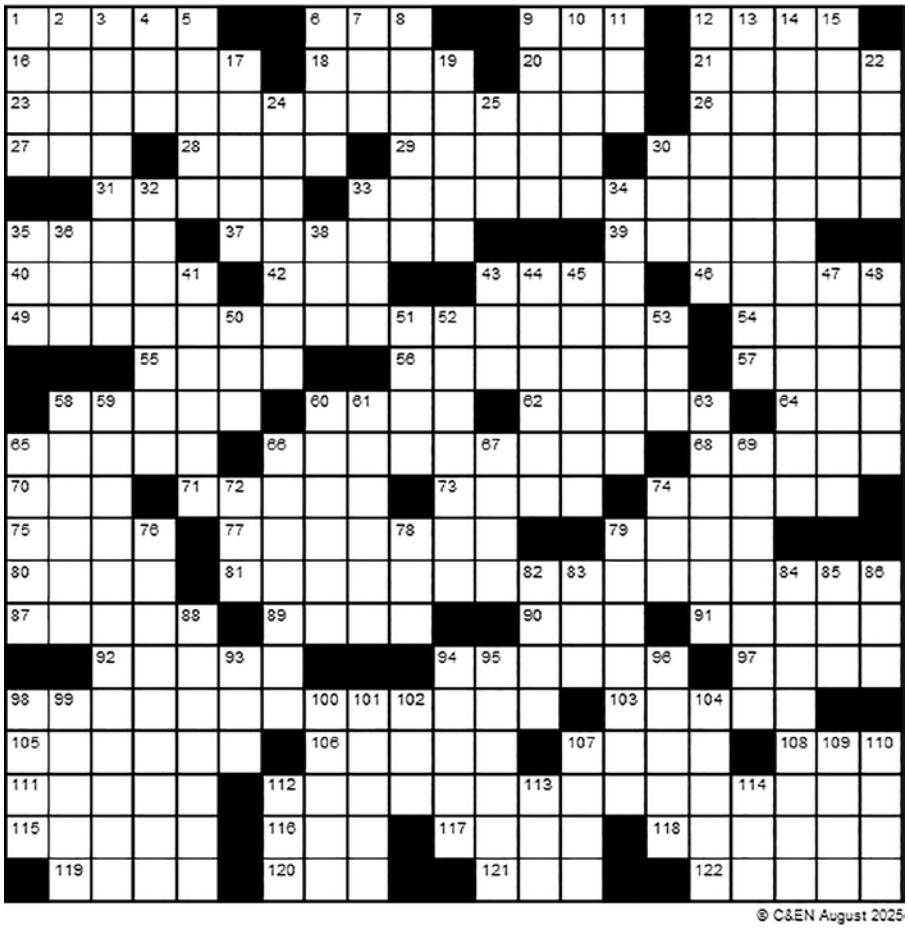
Scan the qr code or go to **https://cenm.ag/wacky-reactions-answers** for the answers

ACROSS

1. Order to a guard dog
6. Put in stitches
9. Separation technique that gives R_f values: Abbr.
12. Church recess
16. Beloved
18. Salaried players
20. Roast or a bone in a roast
21. Spicy alternatives to coffee
23. TeIGeN + ScHIFFEr + BaNKS
26. UFC Hall-of-Famer Rousey
27. Drugmaker Lilly
28. Certain Nashville trophies, for short
29. "Nice delivery, diva!"
30. "Last one in is a ____ egg!"
31. Signs of healing
33. PLaNK
35. On the briny
37. It should come first to all chemists
39. "Halt!" to a salt
40. Show embarrassment
42. Flit (about)
43. Bogey beaters
46. Pulsate
49. HoBBiEs
54. Home to Honolulu
55. I, in Ithaca
56. "We're settling this. Right here. Right now."
57. 1980s IBM computer nicknamed "Peanut"
58. Tequila plant
60. So-called "macaroni of the bride"
62. Co-winner with Katniss in the 74th *Hunger Games*
64. With 48-Down, award-winning documentarian for *Baseball* and *The Civil War*
65. British biscuit served with tea
66. FAmOUS$^+$ SPY$^-$
68. Oak and elm
70. Absorbed, as a cost
71. Palindromic spinner
73. Retained
74. Cable network that's a homophone of headliners in its shows
75. It's just one thing after another
77. "Blitzkrieg Bop" group, with "The"
79. Billy or nanny, e.g.
80. Assert
81. $(FISH)_n$
87. Villeneuve who directed *Arrival* and *Dune*
89. Inception in the movie *Inception*
90. Word before "diem" or "capita"
91. Increase the power of, as an engine
92. Like Jason Bourne, professionally speaking
94. Scoring a 3 or higher on this may earn college credit
97. "____ Go Mets!"
98. FIVEs + SiXeS
103. Spoken for
105. Mental equilibrium
106. Fifth wheel
107. BeBe and ____ Winans (Grammy-winning R&B duo)
108. Hon
111. Make up (for)
112. FeAtUReS OF SeVErAl CLuEs HeRe
115. Ancient language also known as Carthaginian
116. Word before "the question" or "to differ"
117. Continental currency
118. Thread holders
119. Lacrosse stick netting
120. AMA members
121. Gratuity
122. City that hosted the 2020 Summer Olympics in 2021

DOWN

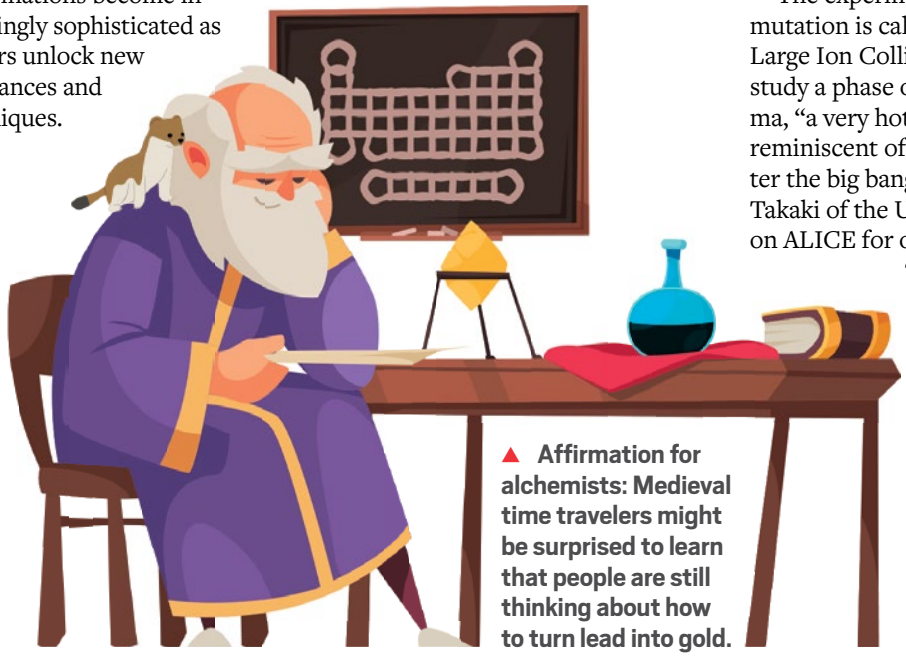
1. Identical
2. Word with "teen" or "matinee"
3. Olympic venue in Los Angeles
4. Palindromic preposition
5. Hajj destination
6. Rejuvenating resorts
7. Drop the ball, so to speak
8. Marsupial with a backward-facing pouch
9. *Three Coins in the Fountain* fountain
10. Pinkish-violet purple
11. "The Eye Network"
12. Trapeze artist
13. Adobe image editor
14. Service that began when a young child accidentally dialed the Continental Air Defense Command (CONAD)
15. Down on a duck?
17. ___ down (makes simpler)
19. "My bad"
22. Silicon dioxide, essentially
24. Garfield's favorite dish
25. Not dis
30. Gun, as an engine
32. Sea north of Iran
33. Foot: Prefix
34. Caught at a rodeo, as a steer
35. Start of a kindergarten song
36. ____-mo (replay technique)
38. Beanie Babies or Razor Scooters, e.g.
41. President who studied mining engineering at Stanford
43. Louvre Pyramid architect
44. All-caps Lady Gaga album
45. Mind big-time
47. "Ya gotta be kidding!"
48. See 64-Across
50. Big-12 athlete in Salt Lake City
51. Terse denial
52. What plots may do
53. Explosive used to shape Mount Rushmore: Abbr.
58. ____ site (of an enzyme)
59. Calls "iso" in a basketball game
60. Video-conferenced
61. Where to emulate natives, in a saying
63. Include, as with an email
65. One getting dressed for lunch?
66. Avogadro, Cannizzaro, Natta, or Volta, e.g.
67. Top-rate
69. Rodent's refuge
72. Unrefined deposit
74. Emergency call that's an ambigram
76. Bite-size treats from Mars
78. Union of teachers, for short
79. Does a hula, maybe
82. SPOILER ALERT: Their planet is Earth
83. Name aptly found in a "dinosaur exhibit"
84. Person keeping no secrets, metaphorically
85. Not safe at home, say
86. Vinyl collectibles: Abbr.
88. Portmanteau relevant to R&D
93. Beyond chill
94. Raptor's nest
95. Like packaged firewood
96. Annual Thanksgiving Day Parade sponsor
98. "It's urgent!"
99. Actor Channing of *Magic Mike* and its sequels
100. Theater guide
101. Downloaded clips, often
102. "Kapow!"
104. Well-groomed
107. Cobblestone onomatopoeia
109. Foe of a foe, maybe
110. Trade name that is a phonetic expression of the initials of Standard Oil
112. Oil derived from marijuana, briefly
113. Shapiro of NPR
114. Ghost's cry



Alchemy in action

In late May, this Newscriptster and two of her nerdiest friends visited the Houston Museum of Natural Science. The museum's recently revamped and expanded matter and motion hall is full of delightful physics and chemistry interactives, including a periodic table dance floor. But the highlight of our visit turned out to be a touchscreen game in a small back gallery designed to look like a 16th-century alchemist's workshop.

The game, called *Alchemy in Action*, involves combining various substances in a quest to discover new elements and compounds. It starts with fire, earth, air, and water, and every new discovery gets added to the players' inventory of options to work with. The combinations become increasingly sophisticated as players unlock new substances and techniques.



▲ **Affirmation for alchemists: Medieval time travelers might be surprised to learn that people are still thinking about how to turn lead into gold.**

For example, burning wood turns it into ash. Combining ash with water makes lye, which can be combined with fat to make soap or electrolyzed to make elemental sodium. The game concludes when the players find all 63 elements on Dmitri Mendeleev's 1869 periodic table.

"The chemistry hall is very forward looking, but at the same time, we wanted to have a gallery that takes you back to the alchemy days," exhibit designer Paul Bernhard tells Newscripts.

Collaboration is a defining feature of the game. The kiosk accommodates up to three players independently experimenting and adding discoveries to a shared periodic table. If one person leaves in the middle of the game, another can hop in and pick up where they left off. Bernhard says that design was an intentional choice to highlight how real-world scientists build on each other's discoveries.

Those looking to download the game are out of luck, though. Bernhard says it's designed to be exclusive to the museum.

Brianna Barbu wrote this week's column. Please send comments and suggestions to newscripts@acs.org.

Physicists turn lead into gold

Turns out, the alchemists' dream of turning lead into gold is technically achievable—it just takes a particle collider!

Physicists at the Large Hadron Collider (LHC) found that the strong electromagnetic field created by near misses between lead (^{208}Pb) atoms traveling at high speed can rip out the requisite three protons and two neutrons to turn some of the nuclei into gold (^{203}Au).

The experiment that detected this transmutation is called ALICE, which stands for "A Large Ion Collider Experiment." ALICE aims to study a phase of matter called a quark-gluon plasma, "a very hot and very dense soup" of particles reminiscent of what the universe was like right after the big bang, says nuclear physicist Daniel Tapia Takaki of the University of Kansas, who has worked on ALICE for over 20 years.

"Lead to gold is one of those things that the experiment was not designed for," Takaki tells Newscripts. The LHC was designed to smash lead ions into each other, but the ALICE researchers found that near misses between the nuclei are interesting to study in their own right.

Understanding these interactions does more than just generate kicky headlines about alchemy, Takaki says. The data provide valuable insight into how to design and build better nuclear physics experiments that account for nuclei spitting out protons and neutrons, which changes the nuclei's trajectory in the collider.

ALICE's analysis found that the LHC produced 86 billion gold nuclei between 2015 and 2018, which seems like a lot but comes out to only 29 picograms, about the same mass as a red blood cell (*Phys. Rev. C* 2025, DOI: 10.1103/PhysRevC.111.054906). And the nuclei exist for only a tiny fraction of a second before falling apart. Sorry, medieval time travelers!

But while you have that time machine up and running, may I suggest traveling back to 2016 to prevent a certain weasel from shutting off the LHC, which not only electrocuted the animal but also (as some have joked on the internet) may have shunted our world into a weirder alternate timeline.

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