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CHEMICAL & ENGINEERING NEWS
OCTOBER 9, 2023

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Scientists warn of environmental impacts amid rush to exploit seabed minerals
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The seafloor is rich in minerals vital for a clean energy future, but extracting them could have long-lasting environmental impacts

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"We should think a bit harder as a society if we really want to engage in deep-sea mining."

—Matthias Haeckel,
marine biogeochemist, Geomar Helmholtz Center for Ocean Research Kiel

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Photograph by NOAA Office of Ocean Exploration and Research, 2019 Southeastern US Deep-sea Exploration/Science Source

Features

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ACS News

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1155 16th St. NW, Washington, DC 20036
202-872-4600 or 800-227-5558

Published by the **AMERICAN CHEMICAL SOCIETY**
Albert G. Horvath, CEO
Sharon Jane Chua, Publisher, C&EN

EDITORIAL BOARD: Christopher Ober (Chair), ACS Board of Directors Chair Paul Jagodzinski, ACS President Judith C. Giordan, John Gavenonis, Manuel Guzman, Xiaosong Li, Amy Ripka

Volume 101, Number 33

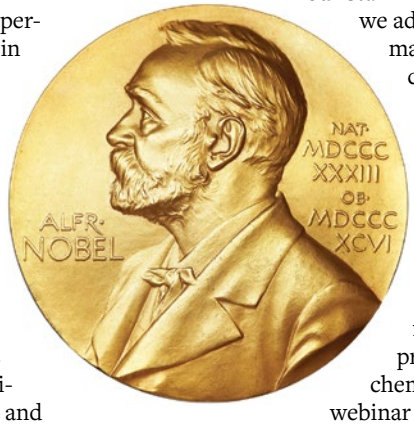
Guest editorial

Making connections

This is a guest editorial by **Chris Gorski**, *C&EN's science news editor.*

As every October arrives, so do the announcements of the winners of the Nobel Prizes in Physiology or Medicine, Physics, and Chemistry. The announcements are covered broadly across media, including wire services, general-interest websites, and publications with specialized audiences like ours. Articles and conversations predicting the likely prizewinners are popular—as we can confirm by looking at the heavy traffic to our yearly webinar and follow-up stories. These stories about research that is often decades old can be rare pieces of science news that nonscientists also seek out.

This year's awards, perhaps more than those in other years, celebrate the discoveries and findings that made important modern technologies possible. The laureates' research enabled the creation of vaccines for COVID-19, made it possible to observe what happens to electrons at fantastically short timescales, and helped researchers fabricate nanoparticles so small that quantum effects determine their colors. Stories about the prizes begin on page 4 of this issue.



I've watched these announcements as a reporter and editor many times before. But this is my first year looking at the prizes specifically through the lens of chemistry.

Many people say the awards don't perfectly reflect modern science, and that's true. The language of Alfred Nobel's will limits the committee to recognizing three scientists per prize. That focus on a few bright stars doesn't always mirror the teamwork and collaboration that exemplify modern science. Moreover, a great number of the awarded scientists have been White and male. Critics have pointed out the committee's lack of recognition of several notable findings by women in particular. Those caveats are important. It's also still true that the Nobels recognize important research.

In March, I began serving as the acting science news editor at C&EN, and I now fill that role in an official capacity. My job is to help our talented and versatile reporters select and refine their news stories for our website and print magazine. As a relative newcomer to this operation, I was struck by two main ideas during the adrenaline- and coffee-charged Nobel week.

First is the adaptability and capability of our team as we responded to the challenges of constructing and publishing stories under tight deadlines. We tried to meet our standards for web presentation, art, and writing while beginning work well before dawn in the US—where many of our staff live and work. In a rarity, we adjusted our workdays to match the schedules of our colleagues in Europe.

Second, each of this year's Nobel Prizes is closely tied to the work that chemists do—crossing traditional disciplines to find the molecular answers to scientific problems. In fact, the most popular prediction for this year's chemistry prize, both in our webinar and many other presentations, was the work that led to messenger RNA (mRNA) vaccines. That research won the prize for physiology or medicine.

Our staff has written numerous times about how attosecond laser pulses—the subject that won the physics prize—are used by chemists in their research. And finally, quantum dots, subject of the chemistry prize, are present in not only labs but also in television screens, lamps, and more.

The applications of the discoveries that this year's prizes recognize will continue to proliferate, perhaps in ways the new laureates can't yet imagine. I was reminded of that as the Nobel committees and the sources our reporters spoke with shared their excitement about the potential of quantum dots and attosecond science. And soon after writing this editorial, I'll have a sharp reminder of what mRNA can do: I'll receive a COVID-19 booster injection.

CREDIT: SHUTTERSTOCK

Views expressed on this page are those of the author and not necessarily those of ACS.

Reactions

▶ *Letters to the editor*

Mohammed Yahia

Please accept our deepest condolences for the loss of Mohammed Yahia, C&EN's new editor in chief. We join the science journalism community as well as his family and friends in grieving his untimely death.

Many of us at the Council for the Advancement of Science Writing first met Mohammed more than a decade ago, when he volunteered to help our group and the National Association of Science Writers develop the 2011 World Conference of Science Journalists. The conference was initially to be held in Cairo. Organizers eventually relocated it to Doha, Qatar.

Despite the challenges that Mohammed then faced in building his early career as an international science journalist, he worked tirelessly to ensure the meeting's success and to build relationships among journalists in his region and worldwide.

In his 20s at the time, Mohammed was already making a difference in science communication. After training and then working briefly as a pharmacist, he had shifted to dedicating himself to bringing reliable, accessible information about health and medicine to the public.

This mission mattered to him. And that commitment was a defining feature throughout his career.

Without question, Mohammed was a bright, talented journalist and a natural organizer. These shining qualities naturally combined to aid his individual accomplishments and leadership efforts in our field. His myriad and generous contributions to science writing, including his part in founding the Arab Science Journalists Association, his job as a regional editor for the Middle East and North Africa at SciDev.Net, and his service as president of the World Federation of Science Journalists from 2017 to 2019, reflect his determination and unusual set of skills.

But Mohammed was always people first. He fostered the careers of many young writers from the Middle East, Africa, and Asia. He cared passionately about helping others succeed.

We knew Mohammed as one of those inspiring people who truly wanted to make the world a better place. As he moved into his new role at C&EN, he clearly held the potential to do even more good for science journalism, international readers, and the public at large. This is only one of the reasons why his death is such a loss for all of us.

We draw some solace, and hope that others do too, in knowing that his memory and legacy will continue to inspire all who work to advance science journalism locally, regionally, and of course, globally.

Board and staff of the Council for the Advancement of Science Writing
Seattle

Tenure

The article on tenure in the Sept. 4 issue of C&EN (page 24) raises the important issue that "few industries offer their employees the long-term job security that tenure grants professors. Why should academia be any different?" Education is not an industry!

Like law and medicine, in higher education, tenure is a license to practice that exacts both proven competence and, of equal importance, a level of responsibility. Physicians and attorneys are licensed to practice for life, subject to standards defined by their accrediting agencies, and federal judges are appointed with lifelong tenure.

Full-time academic positions routinely require candidates upon hiring to have advanced degrees in their chosen disciplines. Tenure candidates serve multiyear "internships," on trial, judged by standards of productivity established by institutions. Finally, their candidacy must be recommended by committees of tenured faculty, usually with tight deadlines.

Most importantly, rather than a paying customer, a professional serves the best interests of a patient in medicine, a client in law, and scholars in the case of a tenured professor.

R. G. "Bob" Landolt
Arlington, Texas

Corrections

▶ **Aug. 7/14, 2023, page 51:** The ACS News article on the Heroes of Chemistry Awards mistakenly omits Enanta Pharmaceuticals from the list of awardees. Enanta was jointly awarded with AbbVie for the design and development of the two antiviral agents in Mavyret.

▶ **Aug. 28, 2023, page 14:** The news article on the social cost of carbon dioxide misstates the nature of US government rules requiring companies to report greenhouse gas emissions. They do in fact exist.

▶ **Aug. 28, 2023, page 26:** The cover story on pollution in the Arctic incorrectly states that the Stockholm Convention on Persistent Organic Pollutants doesn't include per- and polyfluoroalkyl substances. Although it originally did not, some have been added to the convention's annexes.

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Concentrates

Chemistry news from the week

Highlights

NOBEL PRIZE

3 quantum dot researchers awarded Nobel Prize in Chemistry

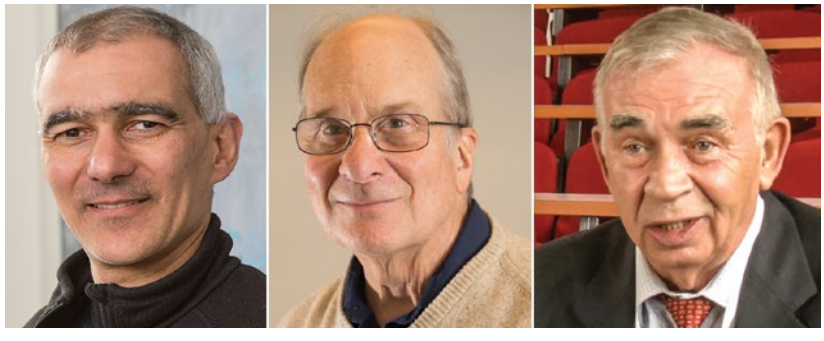
Moungi Bawendi, Louis Brus, and Alexei Ekimov share prize for research that added color to nanotechnology

The 2023 Nobel Prize in Chemistry has been awarded to three researchers "for the discovery and synthesis of quantum dots." Moungi G. Bawendi of the Massachusetts Institute of Technology, Louis E. Brus of Columbia University, and Alexei I. Ekimov, formerly chief scientist at Nanocrystals Technology, will each receive one-third of the 11 million Swedish kronor (about $1 million) prize money.

Quantum dots are semiconductor crystals in the nanometer size range—so small that hundreds of thousands of them can fit across the period at the end of this sentence. Because of the effects of quantum mechanics, these particles exhibit a number of physical properties that uniquely depend on the size of the crystal. For example, how these particles absorb and emit light varies widely between particles that differ just slightly in size. Researchers, including this year's chemistry laureates, have exploited those size-dependent traits to make quantum dots that glow in every color in the rainbow.

In the 1980s, Ekimov showed that optical properties of various types of colored glass were a result of copper chloride nanoparticles embedded in the glass. That work established experimentally the link between the particles' size and quantum effects. A few years later, Brus proved that those effects could be observed in solutions with free-floating particles. And in the 1990s, Bawendi devised chemical methods for synthesizing uniform quantum dots in a range of crystal sizes.

Unlike some fundamental discoveries, the size-dependent characteristics of quantum dots have ushered in a host of commercial applications. One popular example is ultrasharp television screens. These devices prominently display "quantum dots" on the packaging, moving the scientific term from technical parlance to everyday language.



Moungi G. Bawendi (left), Louis E. Brus (center), and Alexei I. Ekimov (right)

In addition to high-end electronic displays, quantum dots have made their way into photovoltaic cells and various energy conversion devices, diodes, lasers, and other specialized light emitters. Quantum dots are also used in biotechnology and medical diagnostics for labeling and tracking cells and in other bioimaging applications.

At the Nobel Prize press conference last week in Stockholm, Johan Åqvist, chair of the Nobel Committee for Chemistry, noted that quantum dots' size-dependent properties extend beyond their colorful nature. The particles' electronic, magnetic, and catalytic properties, and their melting points, all depend critically on their size, he said. Quantum dots offer a way of tailoring materials properties not by changing the material but rather simply by changing the size, Åqvist said. "It's a foundational discovery in nanotechnology."

"Just making quantum dots is easy," Lea Nienhaus of Florida State University writes in an email. "Making perfect quantum dots is a skill few have mastered."

These materials have made an immense impact on inorganic and materials chemistry thanks to groundbreaking synthesis methods for finely controlling the particles' sizes, North Carolina State University's Milad Abolhasani tells C&EN in an email. "These methods enable us to create uniform and customizable nanoparticles for a wide range of applications," he adds. "We're just scratching the surface of what quantum dots can do."

This research has impacted "the way we do medical imaging, sensors, solid-state devices, and now is poised to revolutionize . . . AI and theranostics in medicine," says Rigoberto Advincula of the Oak Ridge National Laboratory in an email.

"I would be at a loss to tell you in 10 years where this is going to go, because I'm waiting for that surprise myself," Bawendi said in a press conference at MIT.—MITCH JACOBY

With reporting by **Brianna Barbu** and **Laura Howes**

CREDIT: MIT (BAWENDI); COLUMBIA UNIVERSITY (BRUS); NEXDOT (EKIMOV)

NOBEL PRIZE

Nobel for medicine recognizes mRNA vaccine research

Karikó, Weissman found nucleoside base modifications that enabled COVID-19 vaccines

Winners of the 2023 Nobel Prize in Physiology or Medicine, Katalin Karikó (left) and Drew Weissman

The 2023 Nobel Prize in Physiology or Medicine has been awarded to Katalin Karikó of Szeged University and Drew Weissman of the University of Pennsylvania for their discoveries concerning nucleoside base modifications that enabled the development of effective messenger RNA (mRNA) vaccines against COVID-19.

Historically, vaccines have used portions of molecules such as proteins or glycans from the surface of viruses or bacteria to train the immune system. Researchers hoped for decades to be able to use DNA and RNA, which encode proteins and can be adapted more easily than proteins, to make vaccines.

However, it was difficult to use mRNA produced in the lab to generate effective, long-lasting immune responses, even after the challenges in delivering the mRNA were resolved. This is because of the two-part nature of the human immune system; the generalist part of the immune system detects and degrades foreign mRNA, launching an inflammatory response.

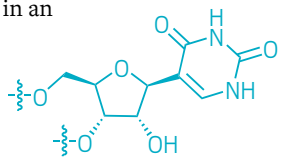
Karikó and Weissman, who met at the University of Pennsylvania in 1997, collaborated to try to use RNA to produce vaccines that could be adapted more quickly. They combined Karikó's expertise in RNA biochemistry with Weissman's in immunology. In a landmark paper published in 2005 in *Immunity*, the pair proved that it was the lack of base modifications in synthetic RNA that made it immunogenic. They showed that converting the RNA base uridine to pseudouridine in mRNA produced in vitro could reduce the inflammatory response (DOI: 10.1016/j.immuni.2005.06.008).

It was, according to Stanford RNA biologist Jin Billy Li, "the first important attempt to try multiple RNA modifications and see how that would activate the immune system." Later, Weissman and Karikó also showed that this modification produced a more stable RNA construct and better protein yields (*Mol. Ther.* 2008, DOI: 10.1038/mt.2008.200).

"Their early discovery that RNA could be modified to avoid detection of the innate immune system now underpins the successful future of RNA vaccine and therapeutics," writes Robin Shattock, a professor of infection and immunity at Imperial College London, in an email to C&EN.

The prize is "really well deserved," says Thomas Carell of the Ludwig Maximilian University of Munich, noting the key role of mRNA vaccines during the COVID-19 pandemic. "They really saved the day," he says. Two companies that used modified mRNA, Moderna and BioNTech, produced vaccines in record time that could protect against COVID-19 infection. In contrast, Carell says, the firm CureVac used unmodified mRNA and never made it to market.

Following the success of mRNA-based COVID-19 vaccines, the pharmaceutical industry has rapidly adopted RNA technology to generate vaccines against other pathogens, such as influenza, and against cancer. Weissman and Karikó have shared a series of high-profile prizes, including the Lasker Award and the Breakthrough Prize in Life Sciences.



Pseudouridine

However, prior to the COVID-19 pandemic, mRNA vaccines were a promising but relatively untested technology. Romesh Subramanian, president and CEO of the RNA biotechnology start-up Ascidian Therapeutics, says that at one point, "nobody believed mRNA could really be a medicine."

"We couldn't get funding; we couldn't get publications; we couldn't get people to recognize RNA as something interesting," Weissman said at a press conference sponsored by the University of Pennsylvania on the day the prize was announced.

Karikó had such difficulty funding her research that she had to leave the University of Pennsylvania; she found work at German company BioNTech. Many scientists who spoke to C&EN highlighted Karikó's resilience and dedication to a vision of RNA therapeutics. Li notes that the adversity Karikó and Weissman faced is not unique. "A lot of people do great science, but they may or may not be fundable based on today's criteria."

According to Kathryn Whitehead, a nanoparticle scientist at Carnegie Mellon University who works on RNA delivery, "It's just a wonderful story of people sticking to their guns and continuing to work in areas that they believed were important. And look at what we have now."

Stefan Hell, a Nobel laureate in chemistry, posted to X (formerly Twitter), "Huge congratulations Katalin! So deserved for the live-saving work that hardly anyone expected a decade ago. Creativity + perseverance is a recipe for real breakthroughs and #NobelPrize."—LAUREL OLDACH

"It's just a wonderful story of people sticking to their guns and continuing to work in areas that they believed were important."

—Katie Whitehead, Carnegie Mellon University

With reporting by **Laura Howes**

CREDIT: PEGGY PETERSON/UNIVERSITY OF PENNSYLVANIA

NOBEL PRIZE

Nobel Prize in Physics awarded to 3 for achievements in attosecond science

Award recognizes advances in probing ultrafast electron dynamics

The 2023 Nobel Prize in Physics has been awarded to three researchers for their contributions to attosecond science. The prize honors Pierre Agostini of the Ohio State University, Ferenc Krausz of the Max Planck Institute of Quantum Optics, and Anne L'Huillier of Lund University. The trio is being recognized for developing "experimental methods that generate attosecond pulses of light for the study of electron dynamics in matter." The scientists will each receive one-third of the 11 million Swedish kronor (about $1 million) prize money.

Tracking molecular scale events, such as vibrations and the making and breaking of chemical bonds, requires ultrafast detection technology. Researchers developed some of those femtosecond (10^{-15} s) methods in the 1990s. But the laser pulses that drive those methods aren't quick enough to track the speedy motions of electrons. That feat requires even shorter light pulses—in the range of attoseconds (10^{-18} s), just a billionth of a billionth of a second. Attosecond laser techniques made their debut in the early 2000s, and it is that work and the field's pioneers being honored with this year's physics prize.

Why probe the motions of electrons on the attosecond time scale? As Eva Olsson, a physicist at Chalmers University of Technology and a member of the Nobel physics committee explained at last week's Nobel Prize press conference in Stockholm, by tracking electrons in real time, scientists can address fundamental properties of materials, such as the time scale of the photoelectric effect. Proposed by Einstein in 1905, that process describes the events that lead to electron emission from materials when they are irradiated.

Attosecond technology can also be used to study the basics of chemistry. For example, the techniques have been used to trace the shape of electron orbitals and to study electron-transfer processes in molecules. Electron- and charge-transfer steps are often the molecular-scale events that kick off redox reactions and other chemical processes.

At the press conference, Mats Larsson, a physicist at Stockholm University and also a member of the prize committee, offered other examples of attosecond applications. He noted that these light pulses can instantaneously boost the electrical conductivity of a dielectric material 18 orders of magnitude. That process abruptly switches insulators to conductors, opening the door to ultrafast electronics.

Attosecond science is even making headway into medicine, Larsson said. The techniques are being used to record molecular fingerprints of compounds in blood samples. That work may eventually lead to methods that recognize subtle differences between samples and detect molecular markers for cancer at the earliest stages of the disease.

Marc Vrakking, a professor of ultrashort physics at the Free University of Berlin, says today's prize is "recognition of the pioneering insights of the field." He says all three laureates deserve the award but notes that unfortunately other scientists who contributed to attosecond science cannot also be recognized, including those who developed the theoretical underpinnings of the experimental work the prize recognizes.

L'Huillier, one of this year's laureates, was teaching when the Nobel committee tried calling her. She finally took the call after the third or fourth attempt to reach her. She said she was so excited by the news that it was difficult to finish her lecture.

"This is the most prestigious prize, and I am so happy to get [it]," she said. "It's incredible. As you know, there are not so many women that get this prize. So it's very, very special."—MITCH JACOBY

Pierre Agostini (left), Ferenc Krausz (center), and Anne L'Huillier (right), the 2023 Nobel laureates in physics

CREDIT: OHIO STATE UNIVERSITY (AGOSTINI); MAX PLANCK INSTITUTE OF QUANTUM OPTICS (KRAUSZ); BBVA FOUNDATION (L'HUILLIER)

"This is the most prestigious prize, and I am so happy to get [it]."

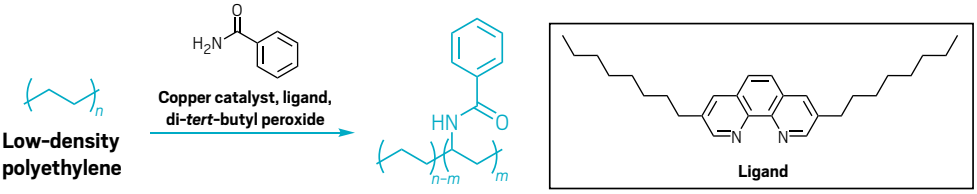
—Anne L'Huillier, physicist, Lund University

POLYMERS

New life for old polyethylene

Reaction converts popular polymer's C–H bonds into C–N bonds

Sandwich bags, milk jugs, and other plastic items made from polyethylene could find new life as upgraded materials. A reaction that converts the popular polymer's C–H bonds to C–N bonds and works on postconsumer materials now opens an avenue to new polymer properties.



"With this reaction, you can now take all of the different polyethylenes—low density, high density, high molecular weight, low molecular weight—and then place a variety of groups on the polymer by making the C–N bond," says John F. Hartwig, a chemistry professor at the University of California, Berkeley, who led the project.

It's possible to dial in a polymer's properties by changing the substituents on the nitrogen that's added to the polymer, says Nicodemo Ciccia, a graduate student in Hartwig's lab and the paper's first author. "The goal was to develop one single method that would allow you to get a whole library of materials," he says.

The reaction is a variation on work Hartwig's lab reported in 2014, in which the chemists used a copper-catalyzed reaction to transform C–H bonds in small alkanes into C–N bonds. But to apply that chemistry to polyethylene, the scientists had to rethink the ligand they used. One with long, alkyl side chains worked best (*Science* 2023, DOI: 10.1126/science.adg6093).

While the researchers worked out most of the chemistry by dissolving the polyethylene in a solvent, they also used the reaction on melted low-density polyethylene without any solvent (shown).

"One of the motivations was to take the waste plastics and convert them into something of higher value," Hartwig says. But the chemists didn't know if their reaction would tolerate the impurities, colors, stabilizers, and plasticizers in postconsumer plastics. Their experiments indicate that it does.

Frank Leibfarth, an expert in polymer chemistry at the University of North Carolina at Chapel Hill, and was not involved with the work, says in an email that "this method will provide polymer scientists a new tool to leverage the most abundant plastic waste feedstocks for new materials discovery efforts, which could contribute an important piece of the puzzle toward realizing a more circular plastic economy."—BETHANY HALFORD

INFECTIOUS DISEASE

Different paths, same goal

SARS-CoV-2 variants thrived by using a variety of strategies to get past the body's first line of defense

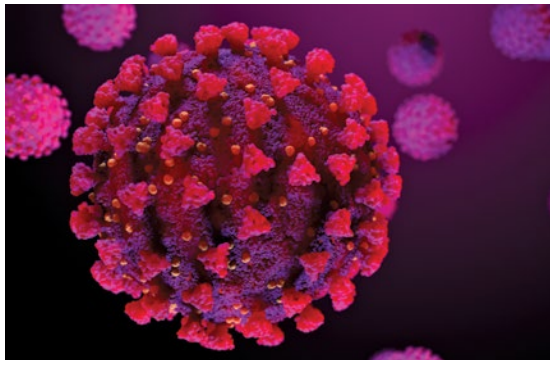
To protect people from acquiring severe COVID-19 infections, researchers have typically targeted SARS-CoV-2's spike protein. "That's important," says Nevan Krogan, a molecular biologist at the University of California, San Francisco. "But there are 28 other genes on the virus."

These protein-coding genes acquired mutations as the virus spread, giving rise to variants. In a recent study, Krogan and his colleagues found that SARS-CoV-2 variants developed mutations linked to specific proteins in the nonspike region that helped the virus multiply and spread rapidly (*Cell* 2023, DOI: 10.1016/j.cell.2023.08.026). Some variants also regulated the expression of certain other nonspike proteins to reach the same end goal to outsmart the body's first line of defense, the innate immune system.

"How the different variants get there follows different mutational trajectories," Krogan says, "but the end result is the same."

A nonspike protein called ORF9b, for example, was involved in allowing the Alpha, Beta, Gamma, and Delta variants of the SARS-CoV-2 virus to evade the innate immune system. Although the original Omicron variant strain, BA.1, was less effective at suppressing this defense, its subvariants, including BA.4 and BA.5, succeeded by producing higher levels of another protein, called ORF6.

The research team is now trying to develop drugs that would reduce the levels of nonspike protein expression or block these proteins from binding to the ones in host cells, says coauthor Adolfo García-Sastre, a molecular biologist at the Icahn School of Medicine at Mount Sinai. The drugs could help slow down or end an existing COVID-19 infection. But in the long run, a "cocktail therapy" that acts on multiple viral targets will be needed, Krogan adds.



In a new study, researchers showed how SARS-CoV-2 variants evolved different ways to ultimately supress the body's innate immune system.

CREDIT: RICHARD JONES/SCIENCE SOURCE

For now, Matthew Frieman, a virologist at the University of Maryland who was not involved in the research, would like to see if the observations Krogan and his colleagues made in human lung cells hold up when animals are subjected to similar changes in key nonspike proteins. "All these interactions have to be validated in multiple systems," he says.—PRIYANKA RUNWAL

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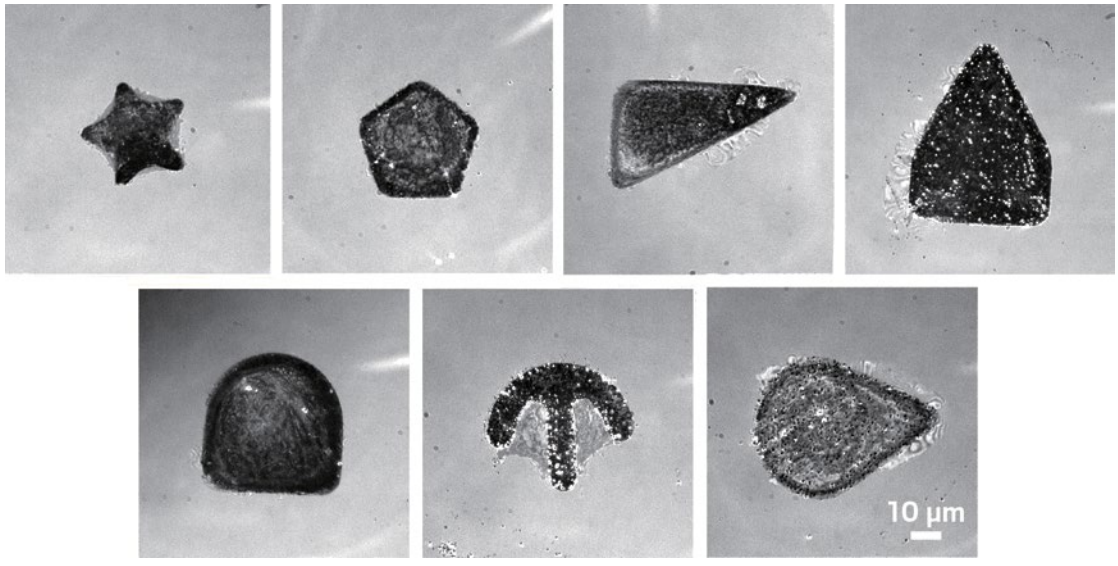
Selections from cen.chempics.org, where C&EN showcases the beauty of chemistry

Bluebirds

When you look at these crystals, do you see birds in flight? Samie Yaseen did when he found them at the bottom of a beaker that had formerly held a copper sulfate solution. He left the solution out for 2 months during summer vacation and returned to find that all the liquid had evaporated, leaving behind large, brilliant-blue copper sulfate crystals. Yaseen is a lecturer and researcher at Duhok Polytechnic University, where he creates copper nanoparticles for sensing pollutants such as the herbicide glyphosate. The phosphate group on glyphosate forms a hydrogen bond to functional groups on the nanoparticle surface, thus triggering the nanoparticles to aggregate and change colors.—BRIANNA BARBU

Submitted by Samie Yaseen



Cells getting bent out of shape

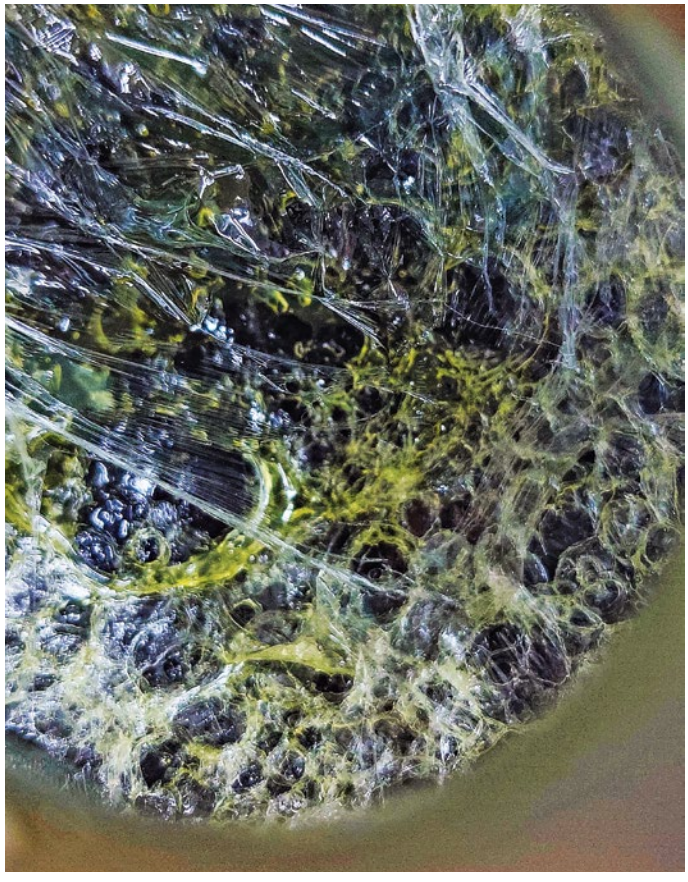
Although the usual image of a cell is an amorphous blob, these mouse cells settled into well-defined polygonal shapes thanks to a patterning system stamped onto the surface the cells are sitting on. To stretch the cells into the shape of their choosing, researchers led by Zheng Liu and Wei Chen of Wuhan University created patterns of DNA-coated nanoparticles by dipping a stamp with various microsized designs on it into a nanoparticle solution and then pressing the stamp onto a glass surface. When the cells came in contact with the stamped patterns, they bound strongly to the DNA and stretched and squeezed to cover each stamped shape. The kicker is that the DNA doubles as a microscopic fluorescent force sensor, so the researchers were able to see how the cells sensed and reacted to strain after they deformed—information that could be useful in tissue engineering.—MANNY MORONE

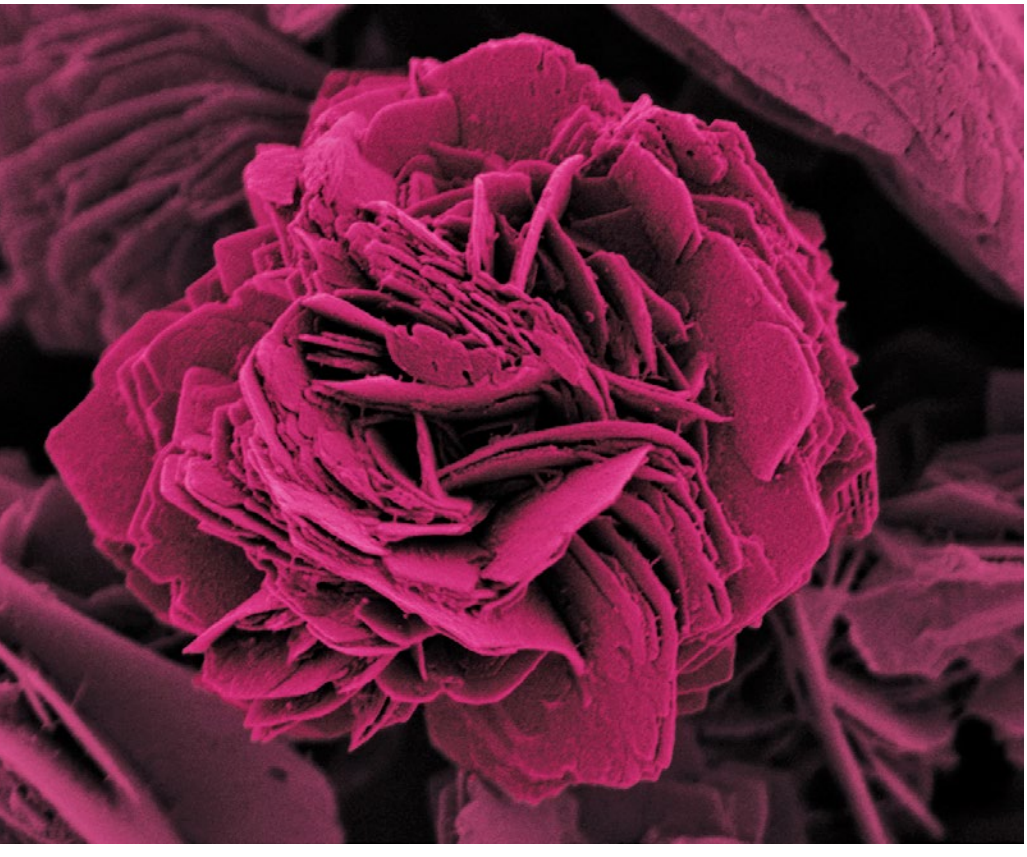
Credit: Feng Sun/Wuhan University

Sugar work

Competitive baking is a hot category in television, and one skill that regularly trips up TV bakers is making dainty decorations using melted sugar. Criss DCosta, a PhD student in Ruchi Anand's lab at the Indian Institute of Technology, takes sugar work to a whole other level, synthesizing derivatives of sugar molecules and exploring their influence on structural biochemistry. She found this otherworldly formation while drying a batch of isomalt, a blend of two sugar alcohols commonly used in low-calorie confections.—CRAIG BETTENHAUSEN

Submitted by Criss DCosta





Drug delivery in bloom

The molecules found inside this rose could be potent antiviral agents. Not because they're newly discovered natural products but because they're small interfering RNA (siRNA) sequences designed to target and silence key genes in chikungunya virus, a mosquito-borne pathogen that currently has no approved vaccine or treatment. And the flower is a porous metal-organic framework (MOF) meant to deliver the siRNA into cells. Shakil Polash is investigating the nucleic acid delivery properties of MOFs as part of his PhD work in Ravi Shukla's lab at the Royal Melbourne Institute of Technology. In addition to targeting viruses, Polash is looking into MOF delivery of siRNA and other nucleic acids, such as plasmid DNA and CRISPR sequences, for cancer treatment. Polash and his colleagues published a paper on their MOF-delivered chikungunya virus gene-silencing efforts last December (*Front. Bioeng. Biotechnol.* 2022, DOI: 10.3389/fbioe.2022.1003448).—BRIANNA BARBU

Submitted by Shakil Ahmed Polash

ACS Campaign for a Sustainable Future

GRANT PROGRAM

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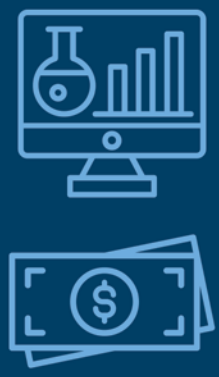
Apply for faculty research grants.



Due September 15, 2023

EARLY CAREER POSTDOCTORAL-FACULTY BRIDGE GRANT

This award provides a post-doctoral associate who plans to launch an independent research career in academia $125,000 in funds to support a post-doctoral associate/fellow for two years once their new research group is launched.

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This award will provide $50,000 to early or mid-career investigators to spend 3–6 months in the laboratory in a private company, national research center, or a different academic institution, with the goal of establishing robust collaborations across industry-academia or across academic disciplines.

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Grant winners will participate in a green chemistry teacher training workshop and commit to teaching a green chemistry course or integrated content.

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The research must be relevant to green and sustainable chemistry, novel, and of scientific merit.

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PHARMACEUTICALS

Lilly bets on radiopharmaceuticals

Big drugmaker to enter field with $1.4 billion purchase of Point Biopharma

Radiopharmaceuticals received a vote of confidence with Eli Lilly and Company's announcement that it plans to acquire the radiopharma developer Point Biopharma Global. The deal will bring Lilly two drugs in advanced clinical trials and several earlier-stage programs, as well as a specialized facility needed to create such medicines.

The $1.4 billion deal marks Lilly's full immersion into the radiopharmaceutical space, although the giant dipped its toes in the water last month by participating in a $175 million series B financing round for Mariana Oncology, whose lead candidate for small-cell lung cancer is set to enter clinical trials next year.

Lilly joins a handful of big pharma companies—notably Novartis and Bayer—that have invested in radiopharmaceuticals. Novartis received US Food and Drug Administration approval in 2018 for Lutathera, a therapy for neuroendocrine tumors, and in 2022 for Pluvicto, which treats prostate cancer. Pluvicto has done particularly well, yielding $240 million in sales in the second quarter.

These drugs will likely compete with Point's two advanced candidate therapies, which are intended to treat address the same indications. Clinical trial results from the firm's prostate cancer drug are expected in the fourth quarter. Considering the timing of the acquisition, there's a good chance Lilly's due diligence suggests that its drug and Novartis's will be comparable in efficacy, Andy Hsieh, a stock analyst at William Blair, wrote in an Oct. 3 note to clients.

In Indianapolis, Point Biopharma Global operates what it says is one of the world's largest radiopharmaceutical facilities.

"We are excited by the potential of this emerging modality," says Jacob Van Naarden, president of Lilly's oncology unit, in a press release announcing the deal. We "see the acquisition of Point as the beginning of our investment in developing multiple meaningful radioligand medicines for hard-to-treat cancers, as we have done in small molecule and biologic oncology drug discovery and development," he adds.

Several other biotechnology companies are developing radiopharmaceuticals. They include Abdera Therapeutics, which has a small-cell lung cancer drug that links radioisotopes to antibodies; Bicycle Therapeutics, which has partnered with Novartis to develop radioconjugates with synthetic peptides; and ARTbio, which is developing multiple drug candidates using a radioactive lead isotope. The field is maturing. More than 350 clinical trials evaluating radiopharmaceuticals are in progress, Hsieh writes.

Developers are exploring different isotopes for such drugs. Most experimental therapies in clinical trials—including both of Point's lead candidates—use lutetium-177, though a significant number use actinium-225 or iodine-131. Some companies are also exploring lead-212 and copper-67.

But sourcing clinical-grade radioisotopes of any flavor has been a hurdle for this class of therapeutics because they need to be generated in a cyclotron or nuclear reactor. Point has a supply deal with ITM Isotope Technologies, a German producer of lutetium-177. It also operates a 17,000 m^2 radiopharmaceutical manufacturing facility in Indianapolis.—ALLA KATSNELSON, special to C&EN

CREDIT: POINT BIOPHARMA GLOBAL (LAB); A-ALPHA BIO (YOUNGER)

INVESTMENT

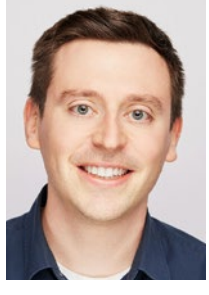
Molecular glue deals abound

Two recent deals in molecular glues come hot on the heels of the launch of Magnet Biomedicine, a glues-focused start-up.

On Sept. 20, Orionis Biosciences said that it would be teaming up with Genentech—owned by Roche—to discover and develop glues; on Sept 26, A-Alpha Bio and Amgen announced that they would be expanding a glue partnership struck last year.

Molecular glues are monovalent small molecules that draw two proteins into close proximity with each other. Often, the target protein will be implicated in disease and the other protein will be an E3 ligase that can label the target protein for destruction.

For $47 million up front, Orionis will aim to discover glues for targets indicated by Genentech in disease areas that include oncology and neurodegeneration. A-Alpha will collect an undisclosed up-front payment as part of its deal expansion with Amgen.



A-Alpha Bio CEO David Younger

As part of their initial collaboration, Amgen shared several drug targets with A-Alpha. The biotechnology firm used its AlphaSeq platform to discover weak interactions between some of Amgen's targets and some E3 ligases in A-Alpha's library, according to CEO David Younger. A-Alpha will now further evaluate certain weakly interacting pairs.—GINA VITALE

CLIMATE CHANGE

European firms advance decarbonization

Investments in purification and electrification are intended to help meet climate targets

Chemical firms in Europe are pushing forward with plans to implement technologies they say will reduce the environmental footprint of existing manufacturing processes. They say the projects are intended to help achieve carbon neutrality in the European Union by 2050.

Arkema is implementing a new purification technology at its acrylic monomer plant in Carling, France, that it says will reduce the site's carbon dioxide emissions by 20%. The firm plans to invest about $135 million in the process.

The Carling facility is one of the major acrylic plants in Europe. It produces monomers used in coatings, adhesives, water treatment, and other markets.

Richard Jenkins, senior vice president of Arkema's coatings division, says decarbonizing existing production processes is part of Arkema's overall climate plan. "It is a journey and requires a combination of levers we can pull to improve how materials are made," he says.

Separately, Solvay announced plans to construct an electric furnace at its silica plant in Collonges, France, by 2025. It says in a press release that the move is part of a "strategic shift towards clean energy sources" and will reduce CO_2 emissions related to silica production by 20%.

And in September, BASF installed the last transformers at a demonstration steam cracker furnace in Germany that is heated with renewable electricity rather than fossil fuel. BASF claims that the approach can reduce CO_2 emissions by 90%.

The European Environmental Bureau (EEB), a nonprofit, says process transformation at chemical plants is an important step toward decarbonization. But the group says the challenge of moving away from fossil-based feedstock remains.

"An electrical cracker will still crack (fossil) naphtha, and its (fossil) tail-gas will be used elsewhere, instead of powering the cracker," Jean-Luc Wietor, the EEB's deputy policy manager for chemicals/sustainable production and best available techniques, says in an email.—VANESSA ZAINZINGER, special to C&EN

Arkema says new purification technology will reduce carbon dioxide emissions at this site by 20%.

CREDIT: ARKEMA

Texas resin plant is on hold again

The PET plant, in the works for a decade, is once again halted as partners reevaluate

A troubled polyethylene terephthalate (PET) project in Corpus Christi, Texas, has once again been mothballed by its owners—Alpek, Indorama, and Far Eastern New Century—which will reevaluate its future in the face of rising costs.

The refrain is familiar for the project, originally undertaken by the Italian chemical company M&G Chemicals a decade ago. At the time, the plant was expected to cost $1 billion and become the largest vertically integrated plant in the Americas to make PET, the resin used in beverage bottles. It is slated to have annual capacity to make 1.1 million metric tons (t) of PET and 1.3 million t of purified terephthalic acid, a PET raw material.

But soon after groundbreaking, financial stresses at M&G weighed on construction. A contractor, Fluor Enterprises, laid off 274 workers in 2017. And firms involved in construction registered about $100 million in liens against the plant due to nonpayment. M&G filed for Chapter 11 bankruptcy in October 2017.

The three current owners, which are among the world's largest PET makers, bought the project out of bankruptcy in 2018. They intend to split the output from the facility between them and market it separately.

But they have had their own problems, halting construction in 2020 because of rising costs and the COVID-19 pandemic. They resumed work in 2022 with the goal of completing the project in 2025.

Alpek now says that construction and labor costs are exceeding expectations. "Consequently, the partners have decided to pause and further assess options to optimize the project's costs and timeline," the company states. "The site will be properly preserved to be able to resume construction in the future."

The world already has plenty of PET capacity. In a presentation at the World Chemical Forum in Houston last month, analyst Ashish Pujari noted that the industry's operating rate—the ratio of demand to production capacity—will soon decline. "We are adding so much capacity in an already oversupplied market that operating rates are bound to touch 60% by 2024 to 2025," he said.—ALEX TULLO

CREDIT: M&G CHEMICALS

The Corpus Christi, Texas, polyethylene terephthalate plant, seen here in 2016, still isn't completed.

MATERIALS

Bolt Threads to go public via SPAC

The biomaterials firm Bolt Threads plans to go public via a merger with a special purpose acquisition company (SPAC). Bolt says the deal will give it a valuation of $346 million and bring in proceeds of at least $35 million. Bolt launched in 2010 with the goal of growing a spider-silk-like material in industrial fermenters for sale as a yarn. But the company now says its lead product is b-silk, a fermented polypeptide that replaces silicones in personal care products.—MICHAEL MCCOY

REGULATION

Albemarle resolves bribery investigations

The US chemical firm Albemarle will pay $218 million to resolve investigations by the US Department of Justice (DOJ) and the US Securities and Exchange Commission. The agencies were looking into a scheme in which the company bribed government officials in Vietnam, Indonesia, and India to retain catalyst sales to state-owned oil refineries between 2009 and 2017. Albemarle disclosed the bribes to regulators in 2018. The DOJ claims that the bribes resulted in profits of nearly $100 million for Albemarle.—MATT BLOIS

HYDROGEN POWER

Another US ammonia plant planned

The fertilizer maker LSB Industries, the industrial gas maker Air Liquide, the terminal operator Vopak Moda Houston, and the Japanese energy firm Inpex are developing a low-carbon ammonia plant on the Houston Ship Channel. The plant will have a capacity of 1.1 million metric tons when it comes on line by the end of 2027. Air Liquide will supply its autothermal reforming technology to produce from natural gas the hydrogen needed for the ammonia. The partners intend to capture 95% of the direct carbon emissions at the facility; they aim to sell most of the output to power plants in Asia.—ALEX TULLO

MERGERS & ACQUISITIONS

Ineos to buy Eastman site

Ineos has agreed to buy Eastman Chemical's site in Texas City for $490 million. The key asset at the complex is an acetic acid plant with annual capacity of 600,000 metric tons per year. The plant's output had long been under contract for sale to Ineos and the previous owner of its acetic acid business, BP. Eastman acquired the facility as part of its $100 million purchase of Sterling Chemicals in 2011. Eastman will continue to own the plasticizer plant on the site, but Ineos will operate it. Ineos also signed a memorandum of understanding to supply vinyl acetate to Eastman. The firms hope to close the transaction by the end of this year. Eastman will continue to make acetyl chemicals in Kingsport, Tennessee.—ALEX TULLO

PETROCHEMICALS

Aramco invests in another Chinese firm

Saudi Aramco is in negotiations with the Chinese firm Jiangsu Eastern Shenghong to buy a 10% stake in its subsidiary Jiangsu Shenghong Petrochemical Industry Group. Shenghong Petrochemical operates an integrated refinery and petrochemical complex, a methanol-to-olefins complex, and a purified terephthalic acid plant in China. Aramco intends to supply Shenghong Petrochemical with crude oil and other feedstocks. In July, Aramco purchased a 10% stake in a larger Chinese petrochemical firm, Rongsheng Petrochemical, for $3.4 billion.—ALEX TULLO

MATERIALS

Solvay to supply composites for plane

Burlington, Vermont–based Beta Technologies has chosen Solvay as its primary supplier of composite materials. Solvay's products will be used in two electric aircraft that Beta is developing: a fixed-wing aircraft and a vertical takeoff and landing aircraft. The planes are being developed for medical, cargo, and passenger transportation.—ALEX TULLO

Beta Technologies planes are rechargable.

CREDIT: BETA TECHNOLOGIES

ENERGY STORAGE

Northvolt plans cathode plant in Canada

The Swedish battery firm Northvolt plans to build a $5 billion manufacturing facility near Montreal that will produce cathode materials and battery cells and will recycle used batteries. The company hopes to begin construction by year-end and start delivering batteries in 2026. The first phase of the project will be able to produce 30 GW h of batteries, but Northvolt aims to subsequently increase that to 60 GW h. The firm says access to low-emission hydropower is a major reason it chose Quebec as the location.—MATT BLOIS

GREENHOUSE GASES

Invista licenses N_2O abatement in China

The polymer producer Invista has licensed its nitrous oxide–abatement technology to three adipic acid facilities in China. Producing adipic acid, a nylon 6,6 raw material, generates large amounts of N_2O, the third-most-emitted greenhouse gas after

carbon dioxide and methane. Invista uses a selective catalytic reduction method at its adipic plant in Victoria, Texas, to break down N_2O into nitrogen and oxygen. Chinese adipic producers have not traditionally abated N_2O. Invista says the projects in China will reduce N_2O emissions by an equivalent of 30 million metric tons of CO_2 per year.—MICHAEL MCCOY

OUTSOURCING

Cambrex completes $38 million expansion

Cambrex has completed a $38 million expansion at its manufacturing plant for small-molecule active pharmaceutical

Cambrex has doubled production of small-molecule active pharmaceutical ingredients at its site in High Point, North Carolina.

ingredients in High Point, North Carolina. The project doubles capacity at the site by adding analytical and chemical development laboratories, two clinical manufacturing suites, and three small-scale commercial manufacturing work centers with 2,000 L reactors. The enlarged operation is intended to coordinate with R&D and continuous-flow process development assets that Cambrex acquired last year with its purchase of Snapdragon Chemistry.—RICK MULLIN

START-UPS

Partners join for catalyst R&D

The start-up Copernic Catalysts will work with Schrödinger to develop better catalysts for making green fuels and bulk chemicals. Schrödinger will use its computational chemistry technology to identify catalyst candidates, and Copernic will synthesize and test them. Copernic was founded in 2021 by Jacob Grose, a former manager at BASF Venture Capital. Its initial target is catalysts for producing zero-carbon ammonia.—MICHAEL MCCOY

VACCINES

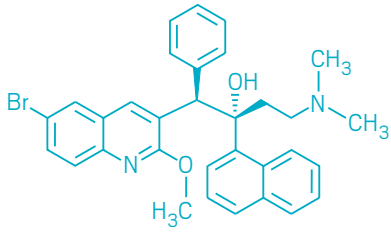
Gritstone advances COVID-19 vaccine

The US Biomedical Advanced Research and Development Authority (BARDA) has given California biotechnology firm Gritstone Bio a contract to advance the firm's next-generation COVID-19 vaccine candidate. The vaccine is based on self-amplifying messenger RNA (samRNA) that encodes the SARS-CoV-2 spike protein and other viral targets. The contract is worth up to $433 million. Gritstone will use the cash to conduct a Phase 2b trial comparing its vaccine with an approved COVID-19 vaccine.—LAURA HOWES

INFECTIOUS DISEASE

J&J will not enforce bedaquiline patent

Johnson & Johnson has confirmed that it will not enforce the patents for its tuberculosis treatment bedaquiline, marketed as Sirturo. The drug's primary patent expired earlier this year; after a public campaign, J&J granted a Swiss



Bedaquiline

nonprofit licenses to produce generic versions. The announcement is intended to reassure other companies that want to manufacture generic versions, the firm says.—LAURA HOWES

Business Roundup

Arkema is spending about $50 million to increase organic acid capacity in Changshu, China. The project will increase output by 2.5 times and is expected to start up in 2025.

Baystar, a joint venture between petrochemical makers Borealis and TotalEnergies, has started a polyethylene plant in Pasadena, Texas, that has capacity of 625,000 metric tons per year. The plant is the first in North America to use Borealis's Borstar technology.

Toray Industries is expanding capacity for carbon fiber at its plant at Abidos, France, by 20%, to 6,000 metric tons per year. The new capacity in medium- and high-modulus fibers will come on line in 2025.

Occidental Petroleum subsidiary 1PointFive and Abu Dhabi National Oil Company have agreed to an engineering study for a direct-air-capture facility in the United Arab Emirates. The plant will have the capacity to capture 1 million metric tons per year of carbon dioxide from the atmosphere for storage in local saline reservoirs.

Odfjell, Alma Clean Power, and DNV plan to install a solid oxide fuel cell system on a ship by the end of 2024. Solid oxide fuel cells are fuel flexible and can use ammonia, methanol, liquefied natural gas, and hydrogen.

Dow, using technology from LanzaTech Global, is introducing a biodegradable surfactant for cleaning products made from industrial carbon emissions. The process converts the emissions into ethanol, which is turned into ethylene oxide, a raw material for the surfactant.

DSM Semichem, a joint venture that includes the South Korean chemical maker Dongjin Semichem, is building an electronics-grade sulfuric acid plant in Plainview, Texas. The facility is intended to serve semiconductor makers in the US.

Biosynth, a Swiss research chemicals supplier, has acquired Pepceuticals, a UK-based producer of synthetic peptides. Biosynth purchased another UK firm, Cambridge Research Biochemicals, in May.

CREDIT: CAMBREX

PERSISTENT POLLUTANTS

EPA finalizes PFAS reporting rule

Agency expands number of PFAS subject to information reporting requirements

The US Environmental Protection Agency wants to know who is using per- and polyfluoroalkyl substances (PFAS), as well as how the chemicals are being used and in what quantities.

Under a final rule released Sept. 28, the agency will require manufacturers and importers of PFAS and of articles containing PFAS to provide information on uses, amounts produced, by-products, potential toxicity and exposures, and disposal methods for PFAS in their products or processes.

Uncertainty over reporting requirements for per- and polyfluoroalkyl substances could disrupt supply chains for industries like semiconductor manufacturing.

Companies must submit the information to the EPA for each PFAS chemical for each year the substance was manufactured or imported since Jan. 1, 2011, "to the extent the information is known or reasonably ascertainable."

The rule gives manufacturers 18 months to provide the information; small manufacturers have 24 months to report PFAS in imported articles.

"The data we'll receive from this rule will be a game-changer in advancing our ability to understand and effectively protect people from PFAS," Michal Freedhoff, assistant administrator for the EPA's Office of Chemical Safety and Pollution Prevention, says in a statement.

The EPA is using its authority under the Toxic Substances Control Act (TSCA) to obtain the PFAS data. The agency is required to do so under a provision in the fiscal 2020 National Defense Authorization Act.

PFAS are persistent in the environment and accumulate in people and wildlife. Some of them are toxic.

The EPA broadened the definition of PFAS in the final rule to include about 100 chemicals that were not in the proposed rule. The agency says the additional substances are likely to be persistent in the environment. They include PFAS with nonadjacent fluorinated carbons, PFAS with unconnected CF_2 or CF_3 moieties, and high-molecular-weight fluoropolymers.

Altogether, at least 1,462 PFAS are subject to the new reporting requirements, according to the EPA.

The American Chemistry Council, which represents chemical manufacturers, says the rule is "another step in the concerning trend of regulatory overreach by this EPA." The group claims that the agency underestimated the reporting burden on industry and the associated costs. "This program represents an unprecedented request for information, both in terms of the amount and type of data requested as well as the number of years subject to reporting."

Other stakeholders say the rule presents both risks and opportunities for manufacturers. "While the EPA's final PFAS reporting rule creates new financial, operational, and supply chain challenges, it also provides even greater momentum for manufacturers to build supply chain transparency," says Cally Edgren, senior director of sustainability at Assent, which helps manufacturers collect and manage supply chain data.

The firm estimates that the cost for companies to comply with the PFAS reporting rule will be over $800 million.—BRITT ERICKSON

C&EN CENTENNIAL

Podcast: Looking back on 100 years of chemistry

The first issue of C&EN was published in 1923 with the stated purpose of "the promotion of research, the development of the chemical industry, and the welfare of the chemist."

The world of chemistry has grown a lot since then, and the magazine has been there to report on it.

To celebrate our 100th anniversary, C&EN reporter and informal historian Alex Tullo has sifted through thousands of issues of the magazine. In this episode, he guides our host Craig Bettenhausen on a tour through its history—from the industrialization of plastics, to the environmental movement, to the modern era of digital publication.

C&EN Uncovered, a project from C&EN's podcast, *Stereo Chemistry*, offers a deeper look at subjects from recent stories. Read Alex's entire series about the C&EN archives at cenm.ag/fromthearchives.—CRAIG BETTENHAUSEN and BRIAN GUTIERREZ, special to C&EN

CREDIT: SHUTTERSTOCK (SEMICONDUCTOR); KAY YOUN/WILL LUDWIG/C&EN/SHUTTERSTOCK (LOGO)

POLLUTION

Researchers find microplastics in clouds

The chemical composition of the plastic pieces suggests they could affect how clouds form

Researchers found microplastics in cloud water collected on Mount Fuji.

Microplastics have infiltrated nearly every corner of the globe. A new study suggests they've made their way into the clouds.

Researchers identified nine types of microplastics in cloud water that they collected from the summit and foothills of Mount Fuji and the summit of Mount Oyama, both of which sit southwest of Tokyo (*Environ. Chem. Lett.* 2023, DOI: 10.1007/s10311-023-01626-x).

The number of microplastic particles that the researchers found in the cloud water was low—between 7 and 14 pieces per liter on average—but that is most likely an underestimate, says Hiroshi Okochi, an environmental chemist at Waseda University and an author of the study. He explains that the collection equipment he and his team used was not originally developed to sample microplastics.

Even so, "it's a unique dataset which fills in some knowledge gaps regarding microplastics environmental distributions," says Denise Mitrano, an environmental chemist at the Swiss Federal Institute of Technology (ETH), Zurich, who wasn't involved in the study.

After collecting the cloud water samples, Okochi and his team analyzed the chemical properties of the microplastics to determine how they might be influencing the atmosphere. The scientists found that the microplastics contained a high number of hydrophilic groups, which form as the plastic deteriorates. "Hydroxyl and carboxyl groups are formed, making it easier to absorb water," Okochi explains in an email.

This finding led him and his team to conclude that, more than just floating in the clouds, these plastics could be playing a role in forming them. That would mean that microplastics could indirectly alter how rain is distributed or change how much solar radiation reaches the ground, Okochi says. "At present, we do not know the extent of this risk, so this is an issue for further study," he adds.

Mitrano agrees that more study is needed, but she is hesitant to draw the same conclusions as Okochi and his colleagues. Just because microplastics are present in clouds doesn't mean they're influencing them, she says. "It could mean that they are just being transported with the airmass," she says in an email.

Even if further research determines that microplastics do play a role in cloud formation, how large an impact they have on the climate remains to be seen. Mitrano suspects their effect is small, except in locations where microplastics could outnumber other cloud-forming particles.—KRYSTAL VASQUEZ

PESTICIDES

RNAi pesticide moves closer to US approval

Potato growers could soon have a new tool for combating the dreaded Colorado potato beetle, which is ubiquitous across the US and quickly develops resistance to chemical insecticides. The Environmental Protection Agency is proposing that for a limited period of 3 years, a new type of pesticide that relies on RNA interference (RNAi) be allowed for use on potato crops.

The US Environmental Protection Agency is on the verge of approving a new type of biopesticide to help control the Colorado potato beetle.

The pesticide's active ingredient, called ledprona, consists of double-stranded RNA (dsRNA). The Colorado potato beetle is highly susceptible to dsRNA, which works by silencing a gene the beetle needs to produce a key protein. With the gene turned off, the insect stops eating and dies from metabolic toxins.

GreenLight Biosciences, the Massachusetts-based biotechnology firm that makes the biopesticide, plans to market it as a sprayable product under the brand name Calantha. Unlike many chemical pesticides, the product degrades quickly in the environment. It is also specific to the Colorado potato beetle, so no other insects are harmed, the company claims.

The EPA approved an experimental use permit in May to test the insecticide in 10 states. That permit requires GreenLight to notify the agency of any safety concerns regarding human health or the environment that arise from the experimental uses. No safety concerns have been reported so far, the EPA says in a Sept. 29 notice announcing the proposal.

If the EPA finalizes the proposal, Calantha would be the world's first sprayable dsRNA pesticide allowed for commercial use on crops. The agency is accepting public comments until Oct. 13.—BRITT ERICKSON

CREDIT: RICHIE JOHNS/FLICKR (FIJI); SHUTTERSTOCK (BEETLE)

At its production facility in Emeryville, California, Upside Foods grows meat in vessels ranging from 1 L bottles to 2,000 L tanks.

CREDIT: UPSIDE FOODS

FOOD

Making cultivated meat cheap

Success will require finding inexpensive ingredients to feed cells

MATT BLOIS, C&EN STAFF

In early 2018, the California-based start-up Memphis Meats, now called Upside Foods, was celebrating progress in its quest to make meat from animal cells grown in a bioreactor—a product that many firms call cultivated meat.

Cultivated meat companies hope to do away with slaughterhouses and to sustainably feed the world's growing population by slashing the amounts of fossil fuel, water, and land required to produce meat. Traditional food companies trying to lower their own environmental footprints are very interested.

Over the previous year, Memphis Meats had served lab-grown chicken to a group of taste testers and raised over $17 million in funding from Cargill, Tyson Foods, and other investors.

But at the time, Memphis Meats' chicken was highly expensive to produce. One of the biggest issues was the cost of growth media: the mix of sugar, proteins, and other nutrients that feed the cells in a bioreactor.

So that summer, the company hired Kevin Kayser, a veteran of the life sciences industry. He had previously led a division of MilliporeSigma that sells growth media to pharmaceutical companies, which use animal cells to produce drugs.

"One of the reasons I was hired was raw material inputs," says Kayser, who was recently promoted to chief scientific officer at Upside. "When I first started, it was top of the list."

Over the past 5 years, Upside and other cultivated meat companies have significantly lowered the cost of growth media, but they will need to lower it even further if they hope to compete with conventional meat producers.

The cost-cutting process begins with firms reducing their use of proteins, the most expensive component of most growth media; the price of those proteins will also have to come down. Another critical step will be moving away from media made with a mix of individually produced amino acids and instead providing those nutrients all together through processed crops.

Today, cultivated meat companies' production is minuscule. Kayser predicts that cultivated meat companies won't demand large quantities of low-cost growth media for years. But he says it's important to build the supply chain before that happens. "You have to work on it now in order to be ready."

Steak without cows

For decades, scientists dreamed of growing animal cells in labs as a way to avoid the many downsides of livestock farming. But the concept was confined to science fiction until 2013, when the Dutch scientist Mark Post produced a hamburger from lab-grown beef cells—at a cost of over $300,000.

Soon after, a handful of start-ups launched to commercialize the technology. California-based Good Meat secured permission to sell cultivated chicken in Singapore in 2020. And this year, Good Meat and Upside started selling cultivated chicken in the US.

At Bar Crenn in San Francisco, a six-course meal that includes Upside's chicken—fried in a recado negro–infused tempura batter and accompanied with burnt chili aioli—costs $150. A tasting menu featuring Good Meat's chicken marinated with anticucho sauce and served with potatoes and ají amarillo chimichurri at China Chilcano in Washington, DC, will set you back $70. Meanwhile, the tab for grabbing a Good Meat chicken lunch at Huber's Bistro in Singapore is under $15.

In all, more than a dozen companies are operating pilot-scale facilities, the largest of which are capable of producing dozens of metric tons of cultivated meat per year, according to a recent report from the Good Food Institute, a nonprofit that advocates for the cultivated meat industry.

In contrast, the Food and Agriculture

Organization (FAO) of the United Nations estimates that conventional slaughterhouses produced 328 million metric tons (t) of meat in 2020.

But producing meat at that scale takes an enormous toll on the planet. Animal agriculture accounted for 17% of humanity's greenhouse gas emissions in 2018, according to the FAO. The meat industry also pollutes the oceans, fouls the air, and reduces the efficacy of life-saving antibiotics.

Cultivated meat companies claim their process will reduce meat's environmental impact, and they're eager to scale up. Upside recently announced plans for a facility near Chicago that it hopes will make 13,000 t of meat per year, and Good Meat is planning a similar-sized facility in the US.

But even with large facilities, cultivated meat isn't likely to be able to compete with conventional meat at the grocery store unless the cost of growth media falls significantly, according to an economic analysis published by a team at the University of California, Davis (*Biotechnol. Bioeng.* 2022, DOI: 10.1002/bit/28324).

Growth media for medical research or drug manufacturing can cost hundreds of dollars per liter, according to David Block, a UC Davis cultivated meat researcher who contributed to the analysis. "To make cultivated meat commercially viable, that number is probably going to have to be $1 per liter or less—so orders of magnitude lower," he said at a conference in September.

Less is more

In addition to basic nutrients like amino acids, many animal cells require specialized proteins to help them proliferate. Those proteins can be extremely costly, so cultivated meat researchers are trying to minimize the amount required or find cheaper alternatives.

Pharmaceutical researchers often supply all the proteins that cells need through fetal bovine serum (FBS), an expensive product made from cow's blood. Cultivated meat companies want to avoid using FBS because it is both costly and an animal-derived product, says Kate Krueger, president of the biotechnology research firm Helikon Consulting.

"Transitioning any kind of product from a research scale to a production scale is going to have to account for the high-value proteins in fetal bovine serum," Krueger says.

FBS works well because it's loaded with dozens of helpful proteins. Albumin is a Swiss Army knife of a protein, with functions such as binding to beneficial molecules and making them available for cells. Transferrin helps cells take in iron. Signaling molecules like insulin and growth factors like basic fibroblast growth factor (FGF2) regulate growth and other cell functions.

Many companies are replacing proteins in FBS with recombinant versions made using fermentation. But recombinant proteins are also expensive, so using fewer of them is critical to reducing costs.

In 2020, the Northwestern University stem cell researcher Paul Burridge began making an FBS-free medium using only a few recombinant proteins. Researchers in David Kaplan's cultivated meat lab at Tufts University adapted the medium to grow cow cells. But the Tufts medium still contained recombinant albumin, which rendered it too expensive for large-scale production of cultivated meat.

Some researchers say that plant versions of albumin or transferrin would be cheaper to use than recombinant proteins, For example, last year, Kaplan's team improved on its medium by replacing recombinant albumin with a substitute from rapeseed, which is grown to make cooking oil. Andrew Stout, then a Tufts graduate student who led the project, produced the protein from agricultural waste using basic extraction methods. "He wanted to take the simplest approach," Kaplan says. "Keep it low cost. Use available sources."

While this low-cost replacement doesn't work for all cells, Kaplan says he's optimistic about switching to plant proteins. "We've made so much progress," he says.

CREDIT: BLUENALU

BlueNalu is aiming to sell whole cuts of sushi-grade tuna.

BlueNalu, a cultivated seafood company based in San Diego, is already using plant-based proteins to eliminate the use of albumin, insulin, and transferrin to grow its tuna cells, according to Lauran Madden, the firm's chief technology officer.

The switch has helped reduce the cost of BlueNalu's growth media by an order of magnitude over the past 5 years. Madden says the firm will likely have to bring costs down by another order of magnitude to make its tuna cost competitive.

In addition to reducing the cost of materials used to grow their cells, BlueNalu and Upside are trying to develop cells that will thrive in leaner growth media.

When Upside scientists select a cell line for cultivated meat, Kayser says, they look for cells that reproduce rapidly or grow at high density. But they also try to pick cells that grow in media with fewer proteins.

"Let's build a process and then select for a cell line that does what we want it to do," Kayser says. "It's going to be a lot more up-front work, but in the end it's going to translate to better cost."

Upside still uses albumin sourced from cows to grow the whole-cut chicken breasts it began selling at a restaurant in San Francisco this year. But Kayser says the cell lines Upside uses to make ground chicken, the product for the planned large-scale facility, don't need any albumin, transferrin, or insulin. The company is also hoping to eliminate the need for albumin in the whole-cut production process.

Growing growth factors

Growth factors, such as FGF2, are the most expensive proteins—and some of the most challenging to remove from growth media. While a bench scientist today might pay a few hundred dollars for a gram of insulin or transferrin, some growth factors can cost millions of dollars per gram, according to a 2020 analysis from the Good Food Institute.

Though growth factors are typically used in quantities of just nanograms per liter of medium, they still need to be cheaper, Kreuger says. These proteins are currently made in small volumes via fermentation for the drug industry, and simply scaling up may be enough to make them affordable for cultivated meat. "That technology is very well known," she says. "The main issue is how to do it at scale."

Laurus Bio, an India-based supplier of growth factors to the drug industry, already plans to boost production for cultivated meat. The company says economies of scale alone will reduce costs by 35%, and it hopes to cut them further by simplifying

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Inclusive images and data visualizations

Use imagery to reflect the diversity of our world and promote inclusion

SABRINA J. ASHWELL, C&EN STAFF

Images are a powerful way to communicate a message. They can cause joy, inspire people to take action, and teach new concepts. But images can also cause distress, demotivate people, and perpetuate stereotypes. The ACS Inclusivity Style Guide—an American Chemical Society guide on inclusive language and images—aims to help people harness the power of images to send messages that reflect the diversity of our world and promote inclusion.

Inclusive images

The guide encourages varying the characteristics of people in images. Characteristics to consider include age, body size and shape, disability status, skin tone, gender expression, and hair style and texture. For example, an image accompanying a C&EN article about international students shows a wide range of people, which helps convey the diversity of students in the US educational system. But often, a single image can't show the full breadth of human experience. So the guide recommends being thoughtful about who you choose to represent and avoiding showing the same combinations of characteristics across all your images.

Inclusive data visualizations

Related to images are data visualizations, such as graphs and charts. Many people consider data to be neutral—they're just facts, after all. But as anyone who has adjusted the axis of a graph knows, the way data are presented can greatly skew the facts and create misconceptions. Each decision related to showing data affects the ultimate message that an audience gets. Which type of visualization will you use? What colors will you choose, and do those colors have connotations? What groups will you include? What will you call them, and how will you order them? What accompanying text is necessary to contextualize the visualization? How did you make the visualization accessible?

The ACS Inclusivity Style Guide aims to help take the guesswork out of inclusive data visualizations by providing guidance on these questions and more. A key piece of advice is to disaggregate data when possible so that more people are visible in the data. Aggregating groups—such as combining all Indigenous groups and multiracial people into an "Other" category—can contribute to their erasure in the data displayed. The guide also encourages communicators to ensure their data visualizations are accessible so that people with disabilities can access the information.

The top tips on making images and data visualizations inclusive are compiled in two tip sheets, shown here and at www.acs.org/inclusivityguide, where you can also find the full ACS Inclusivity Style Guide. We're sharing all the guide's tip sheets in a six-part series in C&EN. I invite you to share feedback on the guide and tip sheets at ISG@acs.org

More online

Like what you've read? See the full guide from the American Chemical Society at www.acs.org/inclusivityguide.

CREDIT: ACS

Images

For more context, review the "Diversity and inclusion in images" section of the Inclusivity Style Guide. Use this tip sheet in combination with the "General guidelines" tip sheet.

Use images that reflect diversity

Aim to use images that show the diversity of our world. Consider skin tone, gender expression, age, disability status, body size and shape, and hair texture. At the same time, ensure the images are authentic and don't just take a "one of each" approach.

Don't perpetuate stereotypes

Ensure depictions of people, including their positions in the image, roles, facial expressions, clothing, and props, do not reinforce stereotypes.

Be accurate

Ensure images accurately depict cultures, and avoid editing photos to artificially show more diversity.

Data visualization

For more context, review the "Data visualization" section of the Inclusivity Style Guide. Use this tip sheet in combination with the "General guidelines" tip sheet.

Identify biased data

Examine data for biases or gaps. Consider the data's context and the potential harm or erasure that may result from how they are presented. Use caution with topics such as crime and public safety.

Design with empathy

Consider whether certain chart types or whether focusing on a smaller range of data might help people connect with the human element of the data.

Disaggregate when possible

Disaggregate data when groups experience dissimilar effects, there isn't a shared history, or members of the community say analyzing these populations together is unreasonable (Urban Institute, 2022). If you lack data on specific subgroups, acknowledge that limitation. Also avoid using an "Other" category.

Handling small data samples

If the sample size for a particular group is very small, avoid omitting the data entirely or noting "not statistically significant" without additional context.

Example

✓ **Use:** The C&EN article "What US Chemists Made in 2022" shows data for all identity groups surveyed, even those with low numbers. To ensure readers could make informed choices about how to interpret the data, the article includes the number of respondents for each group and the note "ACS considers data calculated from fewer than 50 responses unreliable. C&EN included small groups to help make all members visible."

Choosing color in data visualizations

Avoid choosing colors at random without considering their meaning or cultural associations. Recognize when certain colors may perpetuate stereotypes, and prevent introducing distortions in the data.

Ordering groups in data visualizations

Carefully think about the order in which groups are presented and how it might imply a hierarchy. Consider starting with the particular group the study is focused on or sorting the groups alphabetically.

Continued from page 19

postfermentation processing steps.

But CEO Rajesh Krishnamurthy says Laurus Bio won't start using bigger bioreactors to make growth factors until customers are ready to place large orders. "Most of the cultivated meat companies have not reached a scale that may require hundreds of kilograms of these materials," he says. "Unless we have visibility into that demand, we cannot invest."

Other companies think new technologies are a more effective way to reduce costs. The Spanish start-up Cocoon Bioscience hopes to produce growth factors using cabbage moths: while they are in their cocoons, they are injected with a modified virus that induces them to produce a target protein.

Unlike fermentation processes, using moths to produce growth factors doesn't require big investments in bioreactors, CEO Joshua Robinson says. "We don't have that, because our bioreactors are the insects." Cocoon Bioscience hopes to open a facility next year that will be able to make 10–15 kg of growth factors per year.

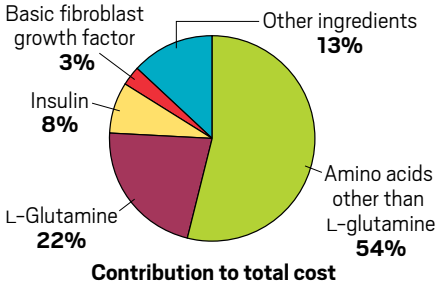
BioBetter, which spun out of Oded Shoseyov's protein engineering lab at the Hebrew University of Jerusalem, aims to make growth factors in genetically modified tobacco plants.

Using tobacco avoids the need for expensive bioreactors and simplifies extraction and purification of proteins, BioBetter says. The firm is already growing tobacco plants that express FGF2. In September, it opened a pilot facility that can produce a few hundred grams of growth factors per year.

"Tobacco in particular is an amazing plant," Shoseyov says. "It can make really complex proteins in a cost-effective manner."

Feeding cells

Researchers at the University of California, Davis, expect amino acids to account for more than half the cost of growth media for cultivated meat once the ingredients are produced at large scale.



Contribution to total cost

Source: *Biotechnol. Bioeng.* 2022, DOI: 10.1002/bit.28324.

Given the progress, says Elliot Swartz, the principal scientist working on cultivated meat for the Good Food Institute, it's only a matter of time before growth factors and other key proteins are affordable enough for cultivated meat producers.

He is more concerned about the cost of basic nutrients. "Amino acids are next on the chopping block," he says.

The new feedlot

While it's possible to eliminate certain proteins from growth media, cells can't live without basic nutrients, including salt, sugars, and amino acids. These are much cheaper than recombinant proteins but are needed in large quantities. The costs add up, particularly for amino acids.

Each amino acid in a typical growth medium is produced separately. Some amino acids, such as lysine, are already produced cheaply via fermentation for the animal feed industry. Others, such as arginine, aren't used as widely.

Scaling them up could lower costs, but not by enough, Swartz says. That's in line with an influential analysis published in 2020 by the chemical engineer David Humbird that concluded individual production of all the amino acids needed for

growth media is not likely to ever be cheap enough for cultivated meat companies.

"That means you can't rely on the existing industry," Swartz says. "You have to start up a whole new supply chain."

Moreover, producing purified, pharmaceutical-grade versions of every ingredient in growth media separately could make cultivated meat's carbon emissions higher than those of conventional meat, according to a report from UC Davis that hasn't been peer-reviewed.

Swartz expects cultivated meat companies to eventually get amino acids from the same place they are starting to get replacements for albumin: plants. Specifically, he points to hydrolysates, which are made by treating plant proteins with heat and acid to break them down into a soup of multiple amino acids.

Providing all the amino acids that cells need in one fell swoop with a hydrolysate would be much more efficient than producing each one individually. But Swartz says researchers are still investigating how to ensure that the amino acids from hydrolysates match up with the ones that cells need. In addition, companies have to make sure that unwanted molecules in a hydrolysate don't slow cell growth.

"It's a hard research and development challenge," Swartz says. "It's not just simply swapping in the amino acids."

Feeding animal cells with hydrolysates made from rapeseed, soy, cottonseed, and other crops would move the cultivated meat industry one step closer to the feedlots it is trying to replace, where animals mostly eat grains supplemented with amino acids and vitamins.

Indeed, cultivated meat companies can learn a lot from farmers, says Susanne Wiegel, head of the alternative protein program at the Dutch animal feed company Nutreco. "Feeding cells isn't that different from feeding animals," Wiegel says.

Nutreco has invested in BlueNalu and Mosa Meat, the start-up founded by Mark Post after he introduced his $300,000 burger. Nutreco helped both firms transition from pharmaceutical- to food-grade amino acids. Mosa Meat estimated that the change would make its production process 100 times cheaper without affecting yield.

Wiegel says amino acids from crop-derived hydrosylates are the next step. "We need to look at how animal feed is done," Wiegel said at an event hosted by the Good Food Institute. "The majority of nutrients are provided through agricultural crops."

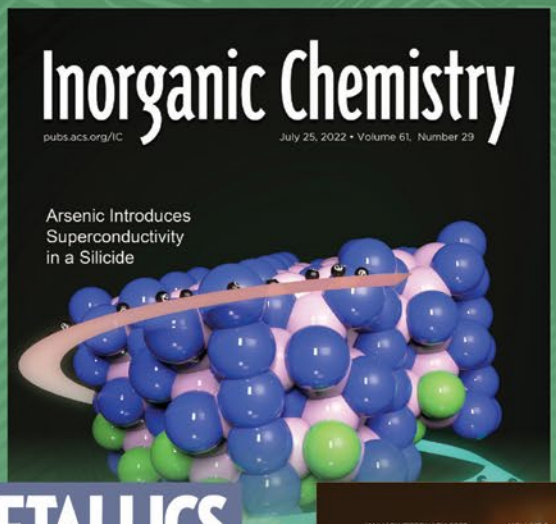
While developing cheaper growth media is still one of the cultivated meat industry's priorities, the progress so far means it's no longer the top concern. A bigger issue now is securing financing for huge bioreactors and transferring pilot-scale processes into those larger plants.

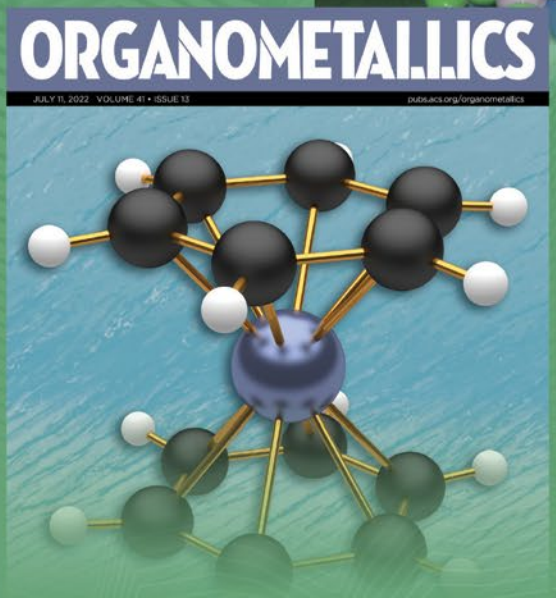
Some companies are already encountering problems as they scale up. The engineering firm building bioreactors for Good Meat has stopped working on the project and is now suing Good Meat for unpaid bills, according to court documents.

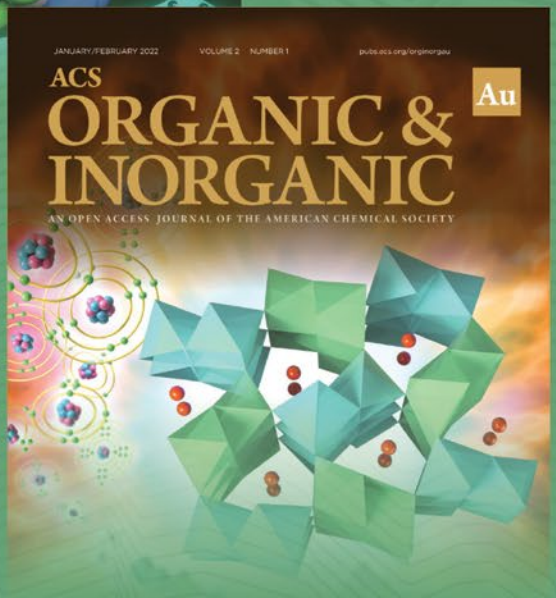
Upside also has a huge challenge ahead. Its current cultivation happens in vessels ranging from 1 L bottles to 2,000 L tanks. At its recently announced plant, the company hopes to eventually use 100,000 L bioreactors, bigger than any ever used to grow animal cells.

Kayser says that Upside is ready to move to commercial scale but that it's unclear if the firm will have to adjust its growth media to work in a bioreactor of that size.

"When you start talking about 100,000 L or greater, I don't know if that's going to take any change in the media," Kayser says. "We haven't gotten to that level." ■







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This vibrant display welcomed attendees to the closing ceremonies of the National Organization for the Professional Advancement of Black Chemists and Chemical Engineers' 50th anniversary event.

CREDIT: JONATHAN FORNEY/C&EN (BOTH)

PEOPLE

NOBCChE celebrates 50 years

At its annual meeting, Black chemical scientist group highlights its past while looking ahead to future progress

JONATHAN FORNEY, C&EN STAFF

There are roughly 76,000 chemists and chemical engineers in the US. Of them, an estimated 5,000 are Black. And of those Black chemists and chemical engineers, 1,500, or about 30%, are members of the National Organization for the Professional Advancement of Black Chemists and Chemical Engineers (NOBCChE, pronounced "no-buh-shay").

These statistics were provided by Simon Shannon, chair of NOBCChE's Board of Directors and director of business development at 3M, to kick off the organization's annual conference, which ran from Sept. 11 to 14.

Shannon celebrated the numbers but said the organization can do more. It wants to raise the share of Black chemists and chemical engineers who are members to 50% by 2025.

Seven Black chemists and chemical engineers founded NOBCChE in 1972 as a way to provide resources to advance themselves and their Black colleagues. While the organization's mission is to promote the advancement of people of color in the chemical sciences, people don't have to be Black to join.

The volunteer-run organization celebrated its 50th anniversary at the conference, held in New Orleans. The group's first annual conference, in 1974, was also held in New Orleans.

In addition to its work with professionals and college students, who were well represented at the annual conference, NOBCChE organizes programming, such as events with regional chapters, to get K–12 students interested in science. In 2024, the organization plans to host a summit, a science fair, and a science bowl for K–12 students.

Mae Jemison, the first woman of color to travel to space, gives the National Organization for the Professional Advancement of Black Chemists and Chemical Engineers gala's keynote address.

This year's conference celebrated all that NOBCChE has accomplished in its 50 years. It also featured events and resources for up-and-coming professionals and students, moments for recognizing the achievements of NOBCChE's members, and plenty of sharing of goals for the future.

"It's important that people leave here with something tangible," said Renã Robinson, NOBCChE's president for 2022–23 and a chemistry professor at Vanderbilt University.

Throughout the week, speakers told attendees that their identities could be tools for gain as opposed to hurdles to overcome. "You bring your experiences and your perspectives to the table," Mae Jemison, the first woman of color to go to space, said in her keynote address. "I would encourage you, every day, to use your perspective."

This sentiment was echoed by Zakiya Wilson-Kennedy, a researcher at Louisiana State University and NOBCChE's 2023 fellow. "Knowing who you are is not insignificant. As young scientists, I encourage you to get to know yourself," Wilson-Kennedy said.

During the state of NOBCChE address on the first day of the conference, Wilson-Kennedy gave a presentation on

her research on an intersectional approach to improving chemistry education, research, and practice.

Wilson-Kennedy's talk emphasized acknowledging and celebrating the benefits of having a diverse student body. She also urged educators to consider a more systematic approach to understanding where their students come from, as opposed to one focused solely on their individual identities. "We also need to start to think of the systems people are moving through," Wilson-Kennedy said.

This year's conference set records for the organization, both in terms of fundraising and attendance. More than $1 million was raised through a combination of sponsors, grants, and exhibitors. The exhibition hall and gala both sold out. There were an estimated 1,000 more hotel rooms booked compared with the last in-person conference.

Many of the attendees were students from regional NOBCChE chapters. The organization has added 22 regional chapters since 2021. There are now 70 chapters around the country, and NOBCChE hopes to expand to additional universities and regions.

Renã Robinson (left), then president of the National Organization for the Professional Advancement of Black Chemists and Chemical Engineers, poses alongside then-president-elect Bridgette Shannon during the conference's awards gala.

CREDIT: JONATHAN FORNEY/C&EN

As the week went on, attendees were invited to talks on chemistry concepts, research-presentation advice, laboratory safety, chemistry education, mentoring, and more. Both undergraduate and graduate students had the chance to present research posters. The winners in each category were honored during the closing ceremonies.

Some of the programming featured well-established Black scientists offering advice to the next generation of chemists and chemical engineers. The presentations emphasized the underrepresentation of Black people in the chemical industry, the need to increase their numbers, and ways to help them have lasting careers.

"You need to be able to communicate up and down," said Candi Hudson, a research branch chief for the US Department of the Interior's Bureau of

Safety and Environmental Enforcement. "You also need to be able to pivot, if necessary."

There were also messages of hope to current students: their futures are not set in stone, and they alone have the power to decide what's best for themselves.

"Don't rush to decide [what to do]," said Victor McCrary, vice president for research at the University of the District of Columbia. "There's always time." McCrary is a past president of NOBCChE and currently serves on the US National Science Board.

The event also offered opportunities to earn scholarships and prizes geared toward career advancement, such as money for travel to future American Chemical Society meetings. ACS has had a memorandum of understanding with NOBCChE since 2016 that includes discount membership programs and other benefits. ACS publishes C&EN.

Two high school students were awarded $50,000 scholarships through a partnership between NOBCChE and the Society for Laboratory Automation and Screening. Shannon said NOBCChE is hoping to resurrect its endowment to be able to give more scholarships in the future.

The week was capped by an awards gala. Some of NOBCChE's founding members congratulated the organization on its achievements in a video tribute. Awards were presented for mentorship, young scientists, outstanding teachers, and others making an impact in their communities and the chemical field.

> "You bring your experiences and your perspectives to the table. I would encourage you, every day, to use your perspective."
>
> **—Mae Jemison,** first woman of color to travel to space

Jemison encouraged attendees to keep pushing for big leaps and discoveries in their work. Such leaps will require interdisciplinary cooperation and compassion, she said. "It is critically important that we stay involved in the extraordinary."

The former astronaut also highlighted the importance of access to quality education and educators' role in protecting the next generation's agency to decide what they want to be. She shared an anecdote about how one teacher, years ago, didn't believe her when she said she wanted to be a scientist.

Jemison spoke to both the progress Black people have made in the sciences over the decades and how much work remains. She said it is not enough to just be in the room; Black people should be actively shaping the work and be confident in their expertise to contribute.

"As leaders, you get to set the metrics of what success is," Jemison said. "We have a world that has remarkable potential and capacities. The world is depending on us to participate."

The gala concluded with board members' recognition of NOBCChE's administrative officers. This acknowledgment also served as a baton pass to the group's next batch of elected leaders.

The event's planning committee took a moment to celebrate 2022–23 president Robinson, whose term ended Oct. 1, and shine a spotlight on then-president-elect Bridgette Shannon, who is a global portfolio manager at 3M.

"All is well for the future of Black chemists and engineers," president-elect Shannon said. ■

A nodule collection vehicle is ready to be launched from a mining ship.

THE DEEP-SEA MINING DILEMMA

The seafloor is rich in minerals vital for a clean energy future, but extracting them could have long-lasting environmental impacts

PRIYANKA RUNWAL, C&EN STAFF

CREDIT: GLOBAL SEA MINERAL RESOURCES

In brief

The seabed is a potentially promising source of critical minerals that are in heavy demand for clean energy technologies. But retrieving those resources comes with long-term environmental consequences. Proponents argue that extracting minerals from the deep sea has fewer impacts on nature and human lives than land-based mining does. A handful of companies and state agencies have recently conducted exploratory tests with the aim of eventually commercializing these underwater reserves. But because we lack international regulations and knowledge of the full environmental effects, many countries are calling for a ban or pause on seabed mining. Whether the International Seabed Authority will allow such a moratorium remains to be seen, but some scientists think it's only a matter of time until mining commences.

Nearly 150 years ago, scientists and sailors set out aboard the HMS *Challenger* to explore the world's oceans. Hauling up a dredge it had dragged along the North Atlantic seafloor, the team found a number of peculiar rocks the size of potatoes. Black, bumpy, and surprisingly lightweight for their size, they were among the first so-called polymetallic nodules to be recovered from the deep sea.

Rich in manganese and iron oxides, such rocks can also contain smaller amounts of valuable metals, including copper, cobalt, and nickel, as well as traces of molybdenum and tellurium.

At the time, the team didn't recognize the commercial potential of these deep-sea mineral reserves. But in the past few decades, nodules have attracted significant mining interest. Proponents of deep-sea mining claim that these underwater deposits could help meet growing demand for critical minerals, particularly those needed for clean energy technologies such as electric vehicle batteries, wind turbines, and solar panels.

"We think nodules are quite marketable right now," says Charles Morgan, a Hawaii-based environmental scientist who has consulted on exploratory seabed mining projects. "There's real excitement about it; there's a lot of investment going on."

On land, mining cobalt and nickel, for example, typically requires slashing large areas of tropical forest and creating open pits to dig out the ore. Such destruction causes pollution, the loss of biodiversity, and the release of carbon stored in trees and soil, thereby contributing to climate change. Mining also harms the health and traditional livelihoods of people living nearby. Some mines are accused of human rights violations, including the use of child labor, in the case of Democratic Republic of Congo's cobalt mines.

Gerard Barron, CEO of the Metals Company, which is at the forefront of the deep-sea mining rush, insists that getting such minerals from the deep ocean will be less environmentally damaging than extracting the land reserves. Retrieving critical minerals from the seabed could also skirt significant social damages.

But experts argue that deep-sea mining is unlikely to halt or reduce terrestrial mining. The process could also severely disturb the marine environment and eradicate unique biodiversity. "It will be a long-term impact," Morgan says. "Anybody who says differently is not telling you the truth."

Since 2001, the International Seabed Authority (ISA), an intergovernmental body in charge of regulating deep-sea mining in waters beyond national jurisdictions, has granted 31 exploratory licenses to private companies and governmental agencies. But the organization is unlikely to approve commercial mining applications until its 36-member council reaches consensus on rules regarding exploitation and the environment. Recent negotiations ended without an agreement, and member states set a 2025 timeline to revise and adopt the regulations.

Meanwhile, many scientists emphasize how little we know about the deep sea and the full environmental consequences of mining there. In a 2021 open letter, they asked for a moratorium on commercial seabed mining. Similarly, some countries, seafood industry groups, financial institutions, and various companies—including Google, Philips, Volvo, and BMW Group—have also called for a complete ban or precautionary pause on deep-sea mining until its impacts are clearer.

Small-scale experimental mining studies have revealed some answers, but many questions remain, says Travis Washburn, an ecologist who worked with the Geological Survey of Japan to study impacts of seabed mining tests. "We still have long ways to go," he says.

HOW DEEP-SEA MINERALS FORM

For mining purposes, companies are focusing on three types of marine mineral deposits. Of greatest interest are polymetallic nodules strewn across the ocean floor about 4,000 m down.

Nodule contents

Nodules recovered from the Clarion-Clipperton Zone contain critical minerals in high demand for clean energy technologies.

Key components

	25 Mn Manganese	28 Ni Nickel	29 Cu Copper	27 Co Cobalt
Percentage of nodule	28.4%	1.3%	1.1%	0.2%
Uses	Steel	Wind turbine	Wire	Rechargeable battery

Source: The Metals Company.

CREDIT: NATURE PICTURE LIBRARY/ALAMY STOCK PHOTO (NODULE); SHUTTERSTOCK/C&EN (GRAPHIC)

Of all deep-sea mineral deposits, polymetallic nodules are of greatest mining interest.

These lumps of rocks can range from the size of grapes to large potatoes. They form when manganese and iron dissolved in seawater precipitate onto small objects, such as shark teeth, shell remains, and rock fragments lying on the seabed. The metals come directly from the water column or from water circulating between grains of soft seabed mud.

Precipitates of manganese oxide and iron oxyhydroxide (FeOOH) accumulate layer by layer at extremely slow rates of 1–10 mm per million years. "It looks like tree rings," says Andrea Koschinsky-Fritsche, a marine geochemist at Constructor University. During the accumulation process, the Mn-Fe compounds also attract and bind other important dissolved minerals, including nickel, cobalt, copper, and lithium.

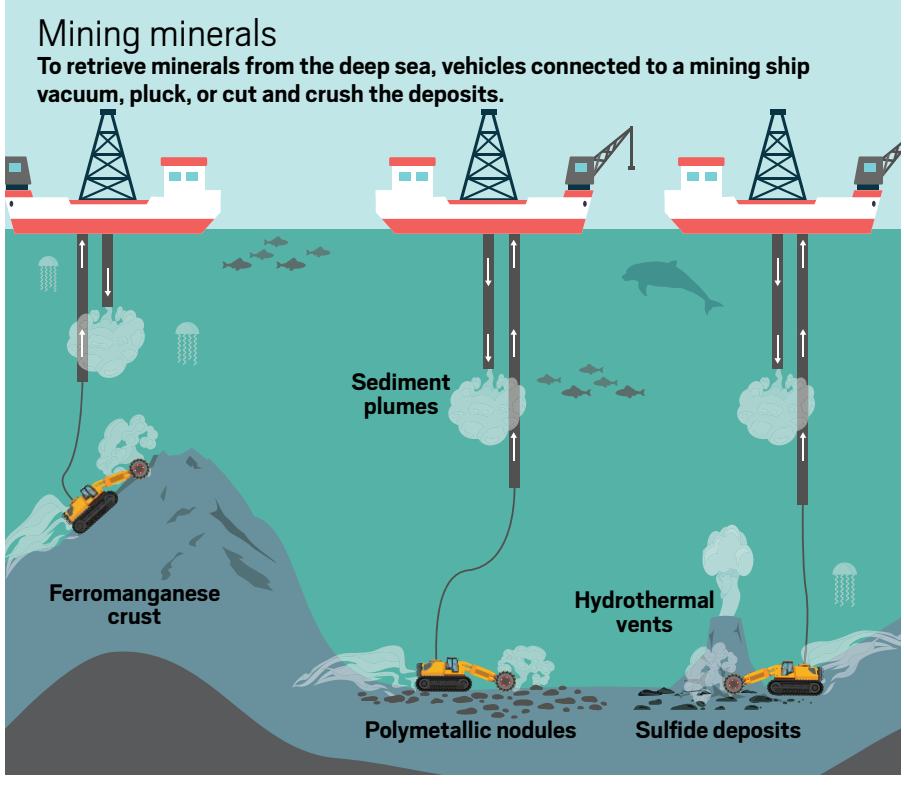
Nodules occur in many ocean areas, and their mineral composition varies between regions. Nodules found in the Indian Ocean basin, for example, are highly enriched in nickel and copper. They also contain high levels of manganese and moderate amounts of cobalt and lithium. Nodules in the Peru Basin are especially rich in nickel and lithium and contain high levels of manganese.

But it's the polymetallic nodule beds of the Clarion-Clipperton Zone in the northeast Pacific Ocean that are of most commercial interest. Spanning between Hawaii and Mexico, this region—roughly the size of Europe—has one of the highest nodule abundances and contains more nickel and cobalt than all terrestrial deposits combined, according to a 2020 report by scientists at the Geomar Helmholtz Center for Ocean Research Kiel.

Another vast mineral reserve comes in the form of crusts that develop on the rocky tops and flanks of underwater volcanic mountains called seamounts. These crusts—typically a few millimeters up to about 25 cm thick—are rich in iron, manganese, and cobalt. Like nodules, they've formed over millions of years. MnO_2 and FeOOH precipitate on the rocky surfaces and bind valuable metals, including cobalt and tellurium. "You need seamounts that are steep enough so that no sediments accumulate on the flanks, giving the crusts a solid surface to grow on," Koschinsky-Fritsche explains.

Some of the thickest and most valuable crusts occur in the central-west Pacific Ocean between Hawaii and the Mariana Islands at depths ranging between 800 and 2,500 m. Referred to as the Prime Crust Zone, this area contains four times as much cobalt and nine times as much tellurium as all known land deposits combined, according to the Geomar report.

A third type of mineral reserve is



CREDIT: THE METALS COMPANY (NODULE); YANG H. KU/C&EN/SHUTTERSTOCK (GRAPHIC)

massive sulfide deposits that form as sulfide-enriched water spouts from tall, chimney-like seabed structures called hydrothermal vents. The process involves interactions between volcanic rocks beneath the ocean floor and heated seawater that dissolves metals and other elements present in the rocks. This hot, acidic fluid spews from hydrothermal vents, precipitating sulfide. The material settles on the seafloor and binds valuable metals, such as zinc, silver, lead, and copper.

As with nodules and crusts, companies can get several desired metals from one package. But extracting every additional metal "costs more money," says James Hein, a marine geologist and former scientific adviser to the ISA's US delegation.

While collecting nodules from the seabed, mining vehicles create sediment plumes that can harm ocean life.

BRINGING UP THE MINERALS

The first step in retrieving these minerals involves sending a robotic collector vehicle to the seafloor. Tethered to a mining ship, this vehicle, equipped with cameras and strong lights, will travel a few hundred or even thousands of meters to reach the dark seabed. Over the past few decades, engineers have built a variety of prototypes that can vacuum, pluck, or cut and scrape these deep-sea deposits.

To collect nodules, for example, *Patania II*, a bus-size prototype developed by Global Sea Mineral Resources, uses seawater to create high-pressure water jets that stir up seafloor sediment and dislodge the nodules. Suction machines vacuum the nuggets along with scattered mud, which is then separated and released back into the sea. The Metals Company used a similar machine as part of its test run last year, during which it collected nearly 3,000 metric tons of nodules from the Clarion-Clipperton Zone.

Extracting crusts and sulfide deposits calls for other types of mining equipment. These deposits are difficult to remove because the crusts stick to the steep and uneven rock surfaces on which they grow, Koschinsky-Fritsche says. Collecting too much rock while mining the crust dilutes the deposit, she adds. Engineers have designed remotely operated vehicles that first peel off the crust and then cut and crush it into roughly paper clip–size fragments. Researchers based in China developed such a prototype and have been testing it to retrieve minerals from crust-coated seamount slopes in the South China Sea.

The same cut-and-crush principle also applies to mining massive sulfide deposits. Nautilus Minerals, a now-bankrupt deep-sea exploration and mining company, had plans to use its remotely controlled vehicle to cut and crush mound-shaped sulfide accumulations at a 1,600 m depth off the coast of Papua New Guinea. The next steps would be to gather this material, pump it to the mining ship, and transport it offshore for further processing.

Japan, on the other hand, successfully tested its prototype in Okinawa's waters and gathered large quantities of sulfide ore in 2017.

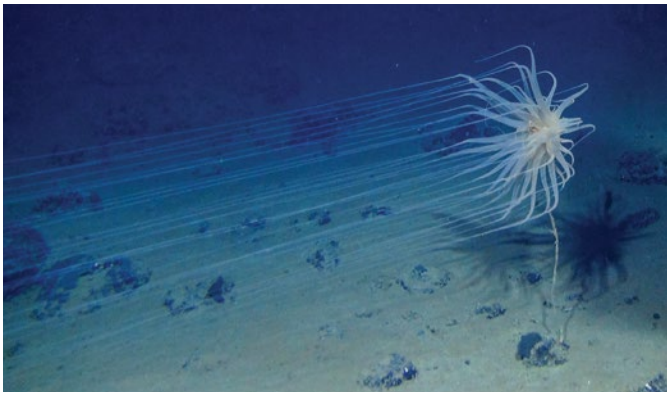
"The technology is there now," Morgan says. "The big problems are regulatory and environmental."

MEASURING MINING'S IMPACT

The greatest impacts of seabed mining will likely come from destroying underwater habitats and permanently removing hard surfaces. On the soft, muddy seafloor, such hard substrates are scarce, and species such as sponges, sea anemones, and xenophyophores rely on nodules to anchor themselves. In a recent modeling study, researchers showed that removing nodules could result in the disappearance of many sponges as well as creatures such as crabs, clams, and small worms that depend on these sessile species (*Sci. Rep.* 2021, DOI: 10.1038/s41598-021-91703-4).

Mining also generates clouds of sediment that can harm ocean critters. These underwater plumes form when mining vehicles rake the seabed or when unwanted sediment and seawater are discharged from mining ships after separating the ore. As this silt makes its way back to the seafloor, it can smother ocean life. The suspended sediment can also clog filtering organs that animals such as corals and sponges rely on to strain their food from water.

In one study of the effects of seabed mining, scientists estimated that a single nodule-mining operation could produce



A marine organism in the genus *Relicanthus* is attached to a dead sponge stalk tethered to a nodule.

Brisingid sea stars are present in deep-sea regions rich in critical minerals.

CREDIT: COURTESY OF THE DEEPCCZ EXPEDITION (PLUME, SEA STAR); DIVA AMON/CRAIG SMITH/UNIVERSITY OF HAWAII (*RELICANTHUS*)

30,000–80,000 m^3 of sediment every day, enough to fill about 4,000–10,000 dump trucks (*Mar. Policy* 2022, DOI: 10.1016/j.marpol.2022.105006). "If this sediment comes by a few times, or once, the animals may be able to clean themselves," says Matthias Haeckel, a marine biogeochemist at the Geomar center and a coauthor of the study. "But if it comes often, it creates stress, and we don't know if they'll be able to deal with that."

The impacts may be local and extend just a few kilometers beyond the mining site as the plume spreads and the sediment settles. But the damages will be long term, Haeckel adds.

As part of a project called MiningImpact, Haeckel and other scientists observed prolonged effects of experimental mining in the Clarion-Clipperton Zone and the Peru Basin. They revisited sites where nodules and the top mud layer had been removed just a few months earlier and nearly 40 years ago. Even after about 4 decades, these sites—anywhere from one-fifth the size of a US football field to about 2,000 football fields—largely lacked sessile creatures and the mobile animals that depend on them.

Also, the microbial activity in these disturbed sites was reduced substantially compared with undisturbed areas nearby. Haeckel says, "That was something we had not expected, that even the microbes have not adapted over decades to this disturbance." But it's understandable, he adds. "You've taken away the surface layer where all the microorganisms live."

In the 2022 study, Haeckel and coworkers predicted that it would take hundreds of thousands of years for the sediment layer to rebuild and millions of years for nodules to regrow. It's worrying, Haeckel says. "We should think a bit harder as a society if we really want to engage in deep-sea mining."

That's especially true when scientists still know very little about the deep sea and the creatures that live there. Recently, a team led by researchers at the Natural History Museum in London identified 5,000 new animal species from an untouched area of the Clarion-Clipperton Zone (*Curr. Biol.* 2023, DOI:10.1016/j.cub.2023.04.052). "And there's millions, possibly tens of millions of species in the deep sea still to be described," Washburn says. Without knowing what's down there, scientists can't understand mining's full impact, he adds.

Also, most studies so far have looked at relatively small-scale disturbances and measured effects over a few years to decades. Commercial mining, on the other hand, will span much larger areas and create noise and light pollution. How environmental consequences will scale remains unknown. "Until we actually do it, we're not going to have all the answers," Washburn says.

CREDIT: THE METALS COMPANY

A nodule collection vehicle is ready to be launched from a mining ship.

TO MINE OR NOT TO MINE

Amid the unknowns and uncertainties, more than 700 scientists and policy experts, over a dozen countries, many environmental nonprofits, and several technology and auto giants have called for a ban or pause on deep-sea mining. Some finance and mining industry experts argue that retrieving minerals from the deep sea and restoring the disturbed landscape will be so expensive that mining doesn't make financial sense, especially when nickel and cobalt reserves on land are sufficient to meet the global demand for decades.

But proponents claim that deep-sea mining will be less environmentally damaging than land-based extraction. In media interviews, the Metals Company's Barron, for example, has said that retrieving critical minerals from the ocean will harm nature less than mining in places such as forests in Indonesia.

So far, no companies or state agencies have submitted commercial deep-sea mining applications to the ISA. But the Metals Company recently announced its plans to file an application next year to start exploiting nodules in an area of the Clarion-Clipperton Zone by 2025.

The ISA's Legal and Technical Commission will have no choice but to consider the company's application even if the official regulations, called the Mining Code, aren't yet in place. The commission can make a recommendation to the council to approve or reject the application or indicate that it's not able to offer a recommendation. In that last case, the application is rejected by default "unless there is sufficient majority at the council to overturn the decision," says Pradeep Singh, an ocean governance expert at the Helmholtz Center Potsdam. Without this Mining Code, "the predominant view now is that perhaps an application should be by default rejected unless the council decides to approve it by the 60% majority," he adds.

Any approval at this stage will be problematic because the ISA has still not defined thresholds for acceptable environmental harm and rules for equitably sharing profits from mining in international waters. "I'm not holding my breath that the regulations will be done soon," Washburn says.

Meanwhile, Morgan thinks that despite the environmental concerns, an international deep-sea mining moratorium won't work. Mining companies have spent millions of dollars on research, infrastructure, and exploratory tests, and they're going to push to make back that money, he says. "Investors are only going to go along with it for so long."

Singh feels otherwise. "I don't think it would be commercially viable at this point in time," he argues. "I wouldn't take it for granted that it will and must happen." ■

COMMENT

Making ACS stronger and more inclusive with global perspectives

SERGIO NANITA, CHAIR, ACS COMMITTEE ON INTERNATIONAL ACTIVITIES

ACS Fall 2023 in San Francisco offered many exciting outcomes for the Committee on International Activities (IAC) and the American Chemical Society's international members. I was thrilled to see the progress ACS made at the meeting to advance its core value of diversity, equity, inclusion, and respect (DEIR).

Most pleasing was the petition presented by the Committee on Nominations and Elections to add international representation on the ACS Board of Directors, which passed at the ACS Council meeting. Although this is an encouraging step forward, the final hurdle is for ACS members to ratify the petition. If you haven't done so already, please vote. This vote is part of the ACS fall election process and runs through Oct. 20, noon (CDT). If the petition is ratified, the international representative will provide the board with much-needed global acumen. Implementation will give ACS members outside the US the opportunity to participate in electing a director to the board for the first time.

CREDIT: CHRISTINE SCHMIDT

The IAC petition to charter an international chemical sciences chapter (ICSC) in Singapore also passed at the council meeting during ACS Fall 2023. This petition now awaits final approval from the board. ACS members in Singapore are eager to launch their chapter and officially become the 27th ACS ICSC.

Over the past year, IAC has made other significant progress to advance its mission of "enabling diverse communities of chemical practitioners worldwide to achieve their goals." Efforts include conducting three ACS International Leadership Summits in partnership with the ACS Global Engagement Office. These meetings were in Rio de Janeiro in November 2022; Marrakech, Morocco, in December 2022; and Kuala Lumpur, Malaysia, in March 2023. The summits provided leadership training for 110 ACS international volunteer leaders from executive committees of 28 international student chapters and 14 ICSCs. Attendees offered innovative ideas, and international student chapters and ICSCs established new collaborations.

In March 2023, ACS approved a suggestion submitted by IAC and the Global Engagement Office to the Innovative Development and Expansion to Advance ACS (IDEA) portal. The project, titled Interim Funding Mechanism for International Chemical Sciences Chapters, provides temporary annual funding for ACS ICSCs for three consecutive years (2023, 2024, 2025) using a model similar to that of ACS local sections. IAC will monitor the benefits and outcomes over this period to enable ACS to make data-driven decisions on permanent annual funding for ICSCs.

IAC also ran a campaign this year to encourage international members to serve on ACS committees. An ACS Committee on Committees report confirmed the campaign's success: significantly more international members submitted a committee preference form than in previous years. I look forward to the value international members will bring to the society by serving on committees and contributing to the diverse ranks of volunteer leaders at ACS for years to come.

My time as IAC chair ends in December. My tenure has involved countless conversations with the global community of ACS members. I have found every interaction enriching, especially those with members whose backgrounds and trajectories are different from mine. I would like to share a few insights that stand out from these conversations and my service with IAC:

- The ACS brand has significance and prestige around the world. It fires up our members and validates the volunteer efforts of the international student chapters and ICSCs.
- Interactions with role models across the diverse leadership of ACS have a positive impact. Volunteers (students and professionals) can be energized through relatively minor outreach, yielding moments of long-lasting inspiration.
- Working by consensus, as done by committees, requires patience and a lot of effort. At times, this process may seem time consuming or even tedious, but it is worth it—particularly when the outcome fulfills broad needs.
- Long-term strategies are important when implementing DEIR initiatives. Engaging students, new ACS members, and emerging leaders of the society in developing these strategies is imperative for sustainable change.
- The global perspectives of international members, including ICSCs, are largely untapped, which is why appointment of an international member to the board, participation across committees, and representation on the council are so important. Appointments throughout ACS governance will allow our society to unleash this potential and to listen more closely to the ideas of our international members.

The ACS brand has significance and prestige around the world. It fires up our members and validates the volunteer efforts of the international student chapters and ICSCs.

On the topic of listening to ideas, please let us know what IAC can do better for the society. We are heading to our strategic planning retreat on Oct. 28 and welcome your input. Please contact us with your comments at intlacts@acs.org.

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

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College educators inspire chemistry students with social justice and advocacy initiatives

ROBIN DONOVAN, ACS STAFF, **AND SARA COTTLE**, C&EN STAFF

College professors across the US are using social justice and advocacy initiatives to get students excited and inspired about their science, technology, engineering, and mathematics (STEM) classes. These projects also give students the intellectual, experimental, and communication skills recommended by ACS guidelines for 2-year and 4-year colleges.

"[These initiatives] exemplify the aspirational goal in the ethics section of the ACS guidelines for 2-year colleges, which asks programs to 'serve the public interest and actively protect the health and safety of co-workers, consumers, and the community,' " says Michelle Brooks, assistant director at the ACS Office of Higher Education.

"Students love it. They want to be more engaged civically," says Sonya Doucette, a chemistry and oceanography professor at Bellevue College. "They just don't know how."

Weaving in social justice

Doucette, together with Heather Price, a chemistry professor at North Seattle College, won US National Science Foundation (NSF) funding for the Climate Justice in Undergraduate STEM: Incorporating Civic Engagement initiative. The initiative will help faculty create course content on the science of climate and environmental change and the effects on communities.

Price engaged her students by helping them explore ways to construct air filters using box fans during a smoky fire season with unusually high levels of air pollution. Students installed particulate matter sensors in various buildings on campus to track indoor air quality as smoke worsened, and they tested various setups to see which best filtered air.

When Price teaches about real-world climate change impacts, she notes how they can disproportionately harm marginalized groups. She says these lessons help her include an equity ethic—principled concerns for social justice—in higher education.

Classes with an equity ethic "give students a feeling of purpose for what they're learning, that they're not going to just be going into the corporate world for the money but that they can actually do something that connects with their community and that helps their community," she says.

Price and Doucette surveyed their students before and after their climate justice coursework. They found that students felt more able to help their communities after taking these classes.

Price adds that it's not enough to show students the science behind climate change. They also need to be taught how to address it in their own communities.

"A doctor would never just give me test results and walk away, right?" she says. "They're going to give you the test results, the science, and then they're going to also give you . . . the information that you need to then repair and heal and fix the problem."

While the NSF funding is specific to STEM, Doucette and Price have used what they've learned to champion efforts to incorporate civic engagement in classwork across their institutions.

Meeting local lawmakers

Teaching students about advocacy is an important part of the ACS Approval Program, a program that promotes excellence in chemistry education for undergraduate students through approval of baccalaureate chemistry programs. The Association of Independent Colleges and Universities of Pennsylvania runs an annual Day on the Hill event at the Pennsylvania State Capitol that allows student lobbyists to meet politicians.

This event helped chemistry and biochemistry professor Loyd Bastin realize how relatively easy it is to meet with state lawmakers. Bastin works at Widener University, which has an ACS-approved chemistry program.

"I got to thinking, We need scientists who will do that [type of advocacy]," Bastin says.

Bastin prepares students in his chemistry courses for the Day on the Hill event. They each summarize a bill that interests them and present it in class. The students then collectively decide which bills to pursue. After researching, they create a white paper with a bulleted summary and supporting evidence for the bill. They also ask fellow students for feedback and gather postcards with messages in support of a bill. In Harrisburg, Pennsylvania, the students hand deliver the materials to the congressional representatives of the postcard writers and their own districts.

A drone view of the Pennsylvania State Capitol located in Harrisburg, Pennsylvania

Bastin's students have advocated for legislation like a bill that would provide funding for cleaning up abandoned coal mines and community greening and beautification in urban areas, among other provisions. Students brainstormed suggestions for funding the bill, including a plastic bag tax, and presented them to their congressional representatives.

STEM students and professionals are uniquely positioned to guide lawmakers: "We can talk about environmental issues, inform legislatures, educate them, and maybe offer some knowledge about the science behind certain bills," Bastin says.

Find more information on the ACS Guidelines for Chemistry in Two-Year College Programs at cenm.ag/2yearchemprograms and the ACS Approval Program at cenm.ag/acsapprovalprogram.

A version of this article was previously published on the ACS website: cenm.ag/climatejusticecurricula.

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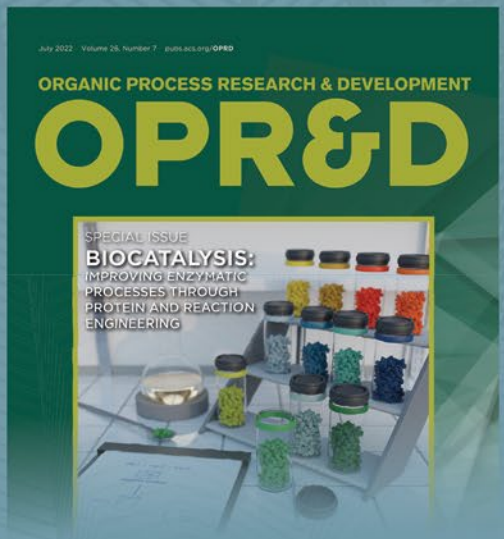

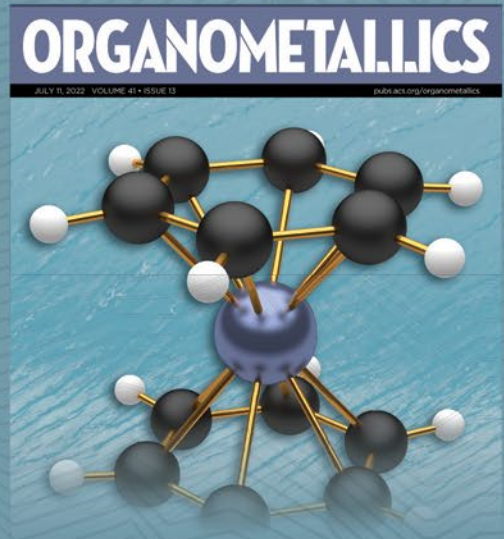

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Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155 16th St. NW, Washington, DC 20036. Periodicals postage is paid at Washington, DC, and additional mailing offices.**POSTMASTER:** Send address changes to: Chemical & Engineering News, Member & Subscriber Services, P.O. Box 3337, Columbus, OH 43210.

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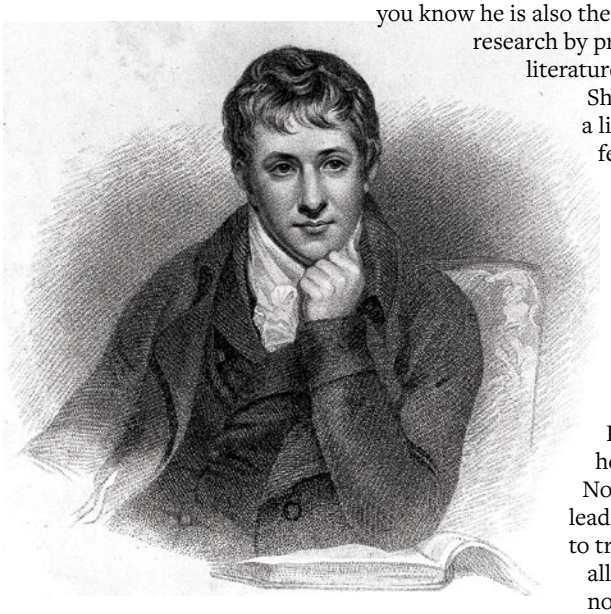
Newscripts

Curating quirky science since 1943

Help transcribe Sir Humphry Davy's notebooks

Sir Humphry Davy is a name well known to many students of chemistry. Isolator of elements and inventor of a safety lamp for miners, Davy was one of the most famous chemists of the late 1700s and early 1800s. But did you know he is also the subject of research by professors of literature?



Chemical literature: Citizen scientists are trying to transcribe Sir Humphry Davy's notes for students of science and literature.

Sharon Ruston, a literature professor at Lancaster University, first became interested in Davy during her PhD research on the poet Percy Bysshe Shelley. Now she's leading a project to transcribe all of Davy's notebooks—notebooks that don't contain just scientific scribbles but poetry as well.

Ruston, whose research focus is the Romantic period, which includes Shelley, Samuel Taylor Coleridge, and Lord Byron, tells Newscripts she was "blown away" when she first realized how much poetry Davy wrote in his notebooks. He seems to have worked on verses even while in the laboratory, and his poetry sometimes shares the page with chemical stains or burn marks, she says. Davy's notes reflect the society of London during the Romantic period and show how the arts and sciences were much more entwined in the past.

But there is a lot of material to sort through and annotate. With over 80 notebooks to go through, Ruston and her research partners have turned to the citizen science platform Zooniverse to transcribe the full corpus of Davy's work. They are in the last stages of the transcription section of the project and have just uploaded the final notebooks to the online platform, Ruston says. There, anyone from around the world can pull up a page and type the text line by line. Multiple participants transcribe each line, and members of the research team then check and combine the results. The plan is that the team will then upload the digitized lines and the images of each page to an online collection for further study. Newscripts is pitching in, and we look forward to finding some key new lyric or verse among the more scientific prose.

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

Chemist cake baker

Newscripts loves a bit of baking. In fact, this page often includes cakes and pastries, and we're not alone. There's a strong correlation between the worlds of chemistry and cuisine.

The latest demonstration of that link has just hit our screens: a chemist in the lineup for this year's *The Great British Bake Off* (*GBBO*, or *The Great British Baking Show*, as it's known in the US).

Josh Smalley is a postdoctoral researcher in James Hodgkinson's laboratory at the University of Leicester, where he cooks up small-molecule probes and proteolysis-targeting chimeras (PROTACs). But he is also now a Baker with a capital *B*, mixing up cakey concoctions and biscuits with just the right amount of bite in the *GBBO*'s famous big white tent.

Bake it: Chemist Josh Smalley is competing in *The Great British Bake Off* this year.

Newscripts reached out to Smalley ahead of his prime-time premier, but alas, no interviews are allowed until after the full series has aired—a reasonable precaution to protect against spoilers, we presume. So we shall just have to share our support here in these pages and via social media.

After we did a bit more emailing to get some details to share with our readers, the *GBBO*'s press office sent Smalley's baker bio and a Q&A document, in which Smalley says he will bring his scientific mind to the baking tent.

"I remember being in the chemistry lab last thing on a Friday when I received the call confirming my place in the famous tent," Smalley says as part of that Q&A. "I was in complete shock and had to sit down on a stool, just lost for words." Newscripts has fingers crossed for Smalley's success.

CREDIT: WELLCOME COLLECTION (DAVY); MARK BOURDILLON/CHANNEL 4 (SMALLEY)

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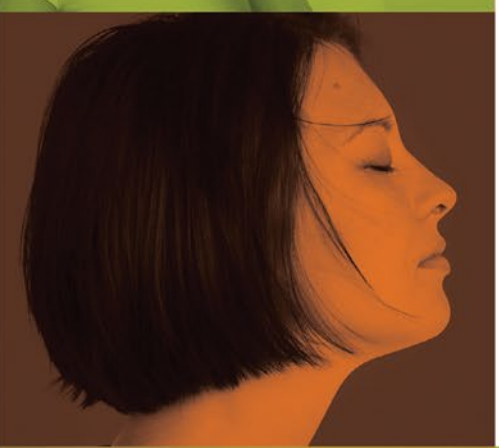

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