Fall/Winter 2019
Massachusetts Institute of Technology
Course X News
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MIT Chemical Engineering Alumni News

X Currents

Guided by AI, robotic platform automates molecule manufacture

New system by the Jensen lab — and new professor Connor Coley PhD ’19 (pictured) — could free bench chemists from time-consuming tasks while helping to inspire new molecules.

Massachusetts Institute of Technology

XCurrents

MIT Chemical Engineering Alumni News

About ChemE

Education
To offer academic programs that prepare students to master physical, chemical, and biological processes, engineering design, and synthesis skills; creatively shape and solve complex problems, such as translating molecular information into new products and processes; and exercise leadership in industry, academia, and government in terms of technological, economic, and social issues.

Research
To provide a vibrant interdisciplinary research program that attracts the best young people; creatively shapes engineering science and design through interfaces with chemistry, biology, and materials science; and contributes to solving the technological needs of the global economy and human society.

Social responsibility
To promote active and vigorous leadership by our people in shaping the scientific and technological context of debates around social, political, economic, and environmental issues facing the country and the world.

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Acknowledgments

From the Department Head

Hello from snowy MIT campus!

As the new year is upon us, I'm happy to share our recent goings-on in the Department. One of the reasons chemical engineering as a field is so exciting, is because it is an environment where once you learn the fundamentals, there is nothing you can't do – the challenge is to find a way to do it. Much in the way our professors Heather Kulik and Connor Coley use AI to find new molecular compounds (see more about new faculty member Connor's work on page 6), our students and researchers use their knowledge and experience to develop new and better materials, sources of energy, and medical devices.

In partnership with Biological Engineering, we have just launched a new maker space on campus to help our students bring to fruition their own novel research and development ideas. The Huang-Hobbs BioMaker Space will officially open in January, and I got a chance to visit the space and talk with alumni Pearl Huang SB '80 and Peter Hobbs '76 SM '81 PhD '85, whose support helped to make the space possible. I look forward to seeing what our students create in this state-of-the-art biomarker space; we are grateful to Peter and Pearl for helping us create this truly amazing resource. Find some photos from the Open House held in November 2019 on page 5.

Sadly, we lost a beloved emeritus professor and alumnus this year: Marcus Karel PhD '60. Marc's long career in food technology and controlled release of active ingredients in food and pharmaceuticals included his tenure at MIT in the Department of Nutrition and Food Sciences/Applied Biological Sciences and in Chemical Engineering over a time spanning from 1960 to 1989. He was recently recognized with an international symposium on Food Engineering given in his honor at the Samberg Conference Center at MIT on May 17, 2016. Marcus remained a thoughtful and contributing member of our Department's community for many years following his retirement, and he will be greatly missed by all. You can read his full obituary on page 22.

In August, alumnus David H. Koch SB '62 SM 63, a long time benefactor to MIT and Chemical Engineering, passed away. David credited his time at the Practice School as a formative experience, and in the 1980s he contributed a major gift that helped ensure its continued excellence for which the Practice School was renamed in his honor. He also served on the Chemical Engineering Visiting Committee for several years, and chaired it from 2011 through 2013, providing undiluted and direct advice that has been invaluable for the Department. His continued support of MIT includes his remarkable contribution to launch the Koch Institute of Integrative Cancer Research, which currently houses five members of our Department and engages many Department members in efforts to understand and address cancer in collaboration with biologists and clinicians. He also contributed the Koch Childcare Center and gave to many other parts of MIT life. As a Department, we are grateful for all that David H. Koch contributed as an alumnus and friend toward Chemical Engineering education on campus and the MIT community.

Finally, we very recently lost Miretta Flitzyani-Stephanopoulos, who was the wife of Professor Greg Stephanopoulos and a former research scientist in our Department. Miretta, also known as Maria, was a Distinguished Professor and the Robert and Marcy Haber Endowed Professor in Energy Sustainability in the Tufts University School of Engineering. She was a highly recognized chemical engineer in her field, but also a wonderful and beloved member of our own ChemE family, and we will miss her greatly.

We are grateful for the support and involvement of all our alumni, and I would love to hear your thoughts and hope to see you on campus. Check out the upcoming events on the back cover – the alumni association is sponsoring a "Graduate Gathering" in March 2020 and we would love to see as many graduate alumni as possible during the event! The alumni association will send out details and registration information in January 2020.

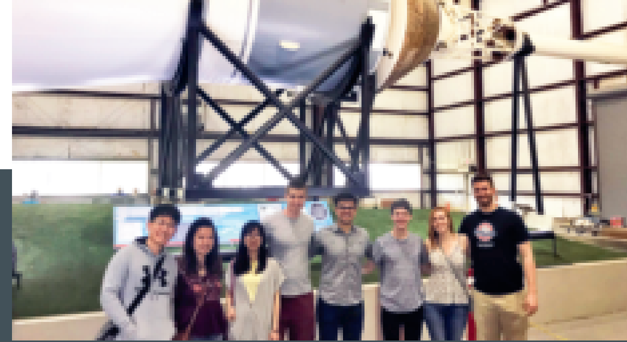
We hope you enjoy this edition of XCurrents and I sincerely thank you for your continued support and friendship.

Sincerely,

Paula T. Hammond

Paula T. Hammond
Department Head

Greetings from the MIT Practice School



Students from the SGCE station visit NASA's Johnston Space Center.

Greetings from the MIT Practice School. Before I share reports from our most recent stations, I'd like to take a moment to remember alumnus David Koch '62 SM '63, who recently passed away. His generous gift to the practice school in the 1980s helped to ensure its future as the only academic program of its kind, a true example of MIT's tenet of "mens et manus." We are thankful to David for his support and our thoughts are with his family during this sad time.

I am also saddened to report that Claude Lupis passed away unexpectedly earlier this fall. Claude was a staunch supporter of the Practice School; he joined the program as a Station Director in 2003, and truly loved his time running stations at a variety of companies, covering a wide range of different technology sectors. He and his wife, Marlyse, were a wonderful team, and were really like a host 'family' to scores of students at stations in Basel, Singapore, Sienna, the UK, Belgium, Brazil, and many locations across the US, from coast to coast. Claude will truly be missed for his enthusiasm and zest for life, and his dedication to the Practice School.

Spring 2019 Stations
Merck Sharp & Dohme Pharmaceuticals, Ireland
Directed by Thomas Blacklock
This March-May Spring Station was split between the MSD manufacturing sites at Ballydine (focusing on small molecule API manufacture and tableting operations) and at Brinny (focusing on the manufacture of non-mammalian cell-derived biologics), both sites in the Republic of Ireland.

The students diligently attacked their problems, and their presentations throughout both sessions went exceptionally well. There was a large attendance at each of the final presentations—in fact, the new plant manager for Ballydine, Brian Killen, was so impressed he even asked the student presenter if he had prior experience with, or was studying, waste water treatment given that he had spoken so knowledgeably about the subject.

Corning, Inc., Corning NY
Directed by Michael Sarli
At the Corporate R&D facility at Sullivan Park (Painted Post, NY), students worked with world class material scientists and engineers and have access to state-of-the-art and, in some cases, leading edge tools and facilities. The winter 2019 session was split between the Corporate R&D facility and Corning's Optical Fiber Engineering organization in Wilmington, NC. At Wilmington, the students worked on projects related to several aspects of fiber manufacture and obtained hands-on experience with large scale pilot plant and commercial production equipment.

Woodside Energy Limited, Western Australia
Directed by Brian Stutts
Building on the successful 2016, 2017, and 2018 Practice Schools, the 2019 Station was sponsored by the Technology Group, with strong support from Process Control Engineering and Data Science. We were able to enjoy working in Woodside's new corporate headquarters—Mia Yellagonga. The opportunity to impact both current and future needs at Woodside was evident across the portfolio of projects, and the students did not disappoint!

SCG Energia, Pasadena TX
Directed by McLain Leonard
As a Practice School Station, we contributed to both the fundamental research & development and process technology arms of the business towards aiding plant startup this fall. The teams' work not only stimulated constructive conversations every week at the update meetings with company sponsors, but also resulted in user-friendly tools that engineers and/or operators plan to use to hasten startup and develop new wax products for future markets.

Summer 2019 Stations
Avantor, Bridgewater NJ
Directed by Robert Fisher
This four week station was our first with Avantor. All three projects required a thorough understanding and application of fundamental chemical engineering principles. These coupled with novel materials and devices associated with emerging technologies were of invaluable assistance. We were quickly embedded into the highly focused day to day operational status of our Avantor sponsors and members of their corporate leadership team.

AstraZeneca, Gaithersburg MD
Directed by Tom Blacklock
At what was previously MedImmune, the biopharmaceutical arm of AstraZeneca, the students were challenged to develop new computational algorithms to evaluate CAR-T cell selection for best in-vivo viability, elucidate the biochemical pathway responsible for an aberrant outcome in a mammalian cell culture, and to develop predictive algorithms for prevention of protein aggregation. Particularly gratifying was that the teams were asked to do encore presentation of their findings to Astra Zeneca's offsite manufacturing plant.

I look forward to continuing to share with you the ongoing experiences of the students and their projects in future newsletters.

Best regards,

T. A. Hatton
Director
David H. Koch School of Chemical Engineering Practice

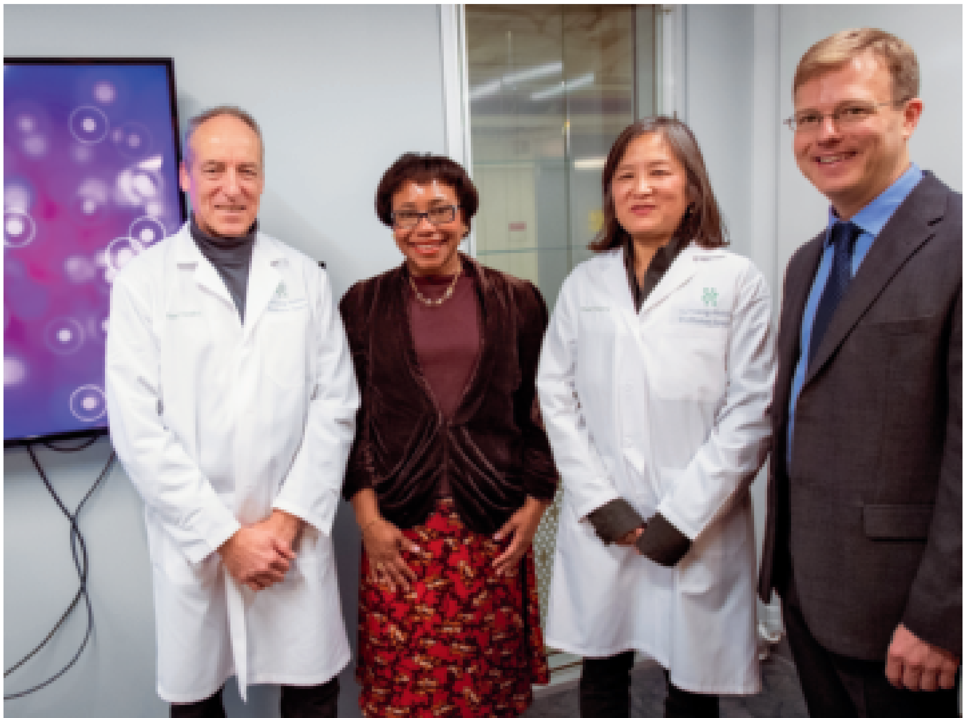
Dedication of the new Huang-Hobbs BioMaker Space

On November 26, 2019, members of the MIT community got a sneak peek at the Institute's newest makerspace, the Huang-Hobbs BioMaker Space, at its official dedication. Sponsored by the Biological Engineering and Chemical Engineering departments, the new facility is slated to officially open in January 2020.

The attendees were joined by alumni Pearl Huang SB '80 and Peter Hobbs '76 SM '81 PhD '85, who have generously made the creation of the space possible. Activities included a tour of the cutting-edge new space and a chance to make commemorative pictures using bacterial photography.

Inaugural director Justin Buck PhD '12 told *The Tech* that the space will be open to "the entirety of the MIT community" to be "used for whatever the student users really want to use it for." The lab will have Biosafety Level 2 capabilities and contain "all the basic equipment," including a tissue culture room, incubators, centrifuges, microscopes, pipettes, thermal cyclers, a refrigerator, a PCR, and common reagents.

MIT students looking to work in the lab must submit a project application and undergo lab training. The lab has a stipulation that allows students to maintain intellectual property of the work they do in the lab and use it to launch their own companies. **X**



Guided by AI, robotic platform automates molecule manufacture

New system could free bench chemists from time-consuming tasks, may help inspire new molecules.

Connor Coley, one of the main architects of the new system, will start his role as assistant professor in the MIT Chemical Engineering Department in August of 2020.

Becky Ham, MIT News Office

Guided by artificial intelligence and powered by a robotic platform, a system developed by MIT researchers moves a step closer to automating the production of small molecules that could be used in medicine, solar energy, and polymer chemistry.

The system, described in the August 8, 2019 issue of Science, could free up bench chemists from a variety of routine and time-consuming tasks, and may suggest possibilities for how to make new molecular compounds, according to the study co-leaders Klavs F. Jensen, the Warren K. Lewis Professor of Chemical Engineering, and Timothy F. Jamison, the Robert R. Taylor Professor of Chemistry and associate provost at MIT.

The technology "has the promise to help people cut out all the tedious parts of molecule building," including looking up potential reaction pathways and building the components of a molecular assembly line each time a new molecule is produced, says Jensen.

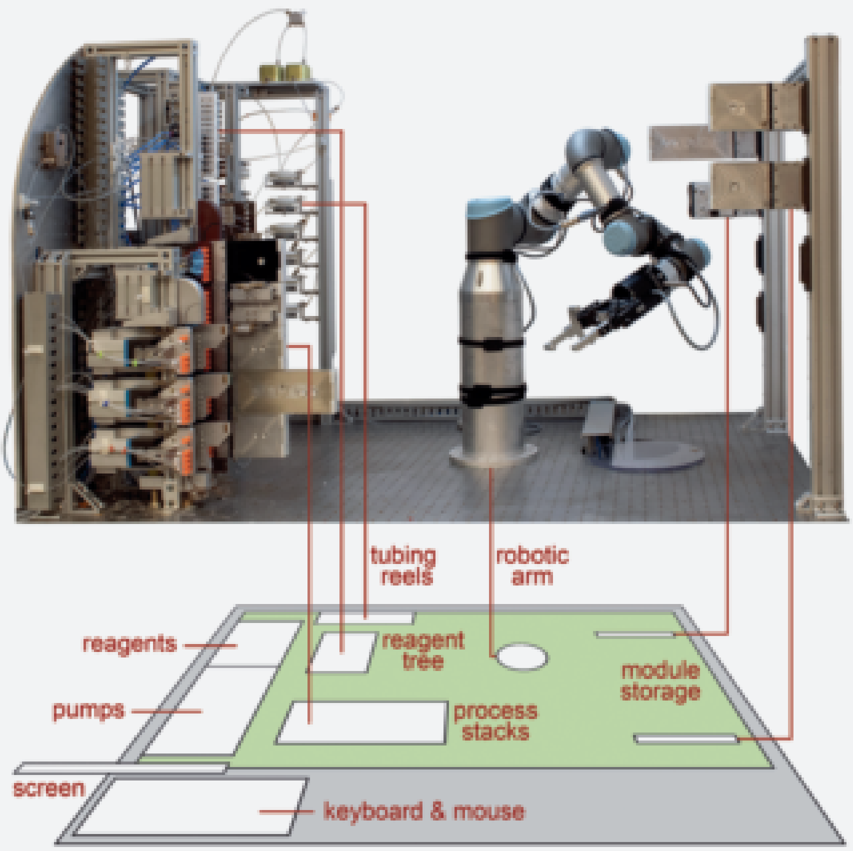
"And as a chemist, it may give you inspirations for new reactions that you hadn't thought about before," he adds.

Other MIT authors on the Science paper include Connor W. Coley, Dale A. Thomas III, Justin A. M. Lummiss, Jonathan N. Jaworski, Christopher P. Breen, Victor Schultz, Travis Hart, Joshua S. Fishman, Luke Rogers, Hanyu Gao, Robert W. Hicklin, Pieter P. Plehiers, Joshua Byington, John S. Piotti, William H. Green, and A. John Hart.

The new system combines three main steps. First, software guided by artificial intelligence suggests a route for synthesizing a molecule, then expert chemists review this route and refine it into a chemical "recipe," and finally the recipe is sent to a robotic platform that automatically assembles the hardware and performs the reactions that build the molecule.

Coley and his colleagues have been working for more than three years to develop the open-source software suite that suggests and prioritizes possible synthesis routes. At the heart of the software are several neural network models, which the researchers trained on millions of previously published chemical reactions drawn from the Reaxys and U.S. Patent and Trademark Office databases. The software uses these data to identify the reaction transformations and conditions that it believes will be suitable for building a new compound.

"It helps makes high-level decisions about what kinds of intermediates and starting materials to use, and then slightly more detailed analyses about what conditions you might want to use and if those reactions are likely to be successful," says Coley.



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"One of the primary motivations behind the design of the software is that it doesn't just give you suggestions for molecules we know about or reactions we know about," he notes. "It can generalize to new molecules that have never been made."

Chemists then review the suggested synthesis routes produced by the software to build a more complete recipe for the target molecule. The chemists sometimes need to perform lab experiments or tinker with reagent concentrations and reaction temperatures, among other changes.

The final recipe is then loaded on to a platform where a robotic arm assembles modular reactors, separators, and other processing units into a continuous flow path, connecting pumps and lines that bring in the molecular ingredients.

"You load the recipe — that's what controls the robotic platform — you load the reagents on, and press go, and that allows you to generate the molecule of interest," says Thomas. "And then when it's completed, it flushes the system and you can load the next set of reagents and recipe, and allow it to run."

The new system is entirely configured by the robotic platform. "This gives us the ability to sequence one molecule after another, as well as generate a library of molecules on the system, autonomously," says Jensen.

The design for the platform, which is about two cubic meters in size — slightly smaller than a standard chemical fume hood — resembles a telephone switchboard and operator system that moves connections between the modules on the platform.

"The robotic arm is what allowed us to manipulate the fluidic paths, which reduced the number of process modules and fluidic complexity of the system, and by reducing the fluidic complexity we can increase the molecular complexity," says Thomas. "That allowed us to add additional reaction steps and expand the set of reactions that could be completed on the system within a relatively small footprint."

"We are really trying to close the gap between idea generation from these programs and what it takes to actually run a synthesis," says Coley. "We hope that next-generation systems will increase further the fraction of time and effort that scientists can focus their efforts on creativity and design." X

This is a condensed version of the original article. For the full version, go to news.mit.edu

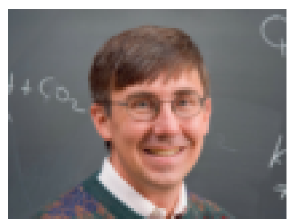
Faculty Highlights

Martin Bazant wins MITx Prize for Teaching and Learning in MOOCs
Martin Bazant has won the third annual *MITx* Prize for Teaching and Learning in MOOCs — an award given to educators who have developed massive open online courses (MOOCs) that share the best of MIT knowledge and perspectives with learners around the world. Bazant received the MITx prize for his course, 10.50.1x (Analysis of Transport Phenomena Mathematical Methods). Most problems in the course involve long calculations, which can be tricky to demonstrate online. To solve this challenge, Bazant broke up problems into smaller parts that included tips and tutorials to help learners solve the problem while maintaining the rigorous intellectual challenge.

Richard Braatz wins 2019 AIChE Separations Division Innovation Award
This award recognizes outstanding contributions to scientific, technological, or industrial areas involving separations technologies. Criteria considered in selecting an awardee include development and implementation of significant discoveries, creative research, or new processes and/or products. The innovation should have demonstrated significant and measurable commercial, environmental, or societal value.

Kwanghun Chung wins 2019 Presidential Early Career Award
Chung was among the more than 300 recipients of the 2019 Presidential Early Career Awards for Scientists and Engineers (PECASE), the highest honor bestowed by the U.S. government to science and engineering professionals in the early stages of their independent research careers.

Karen Gleason named AIChE John M. Prausnitz Institute Lecturer
Each year the Executive Board of AIChE's Program Committee invites a distinguished member of AIChE to present a comprehensive authoritative review of the chemical engineering science in his or her field of specialization. Selection criteria include the quality and relevance of the accomplishments of the lecturer in the technical field likely to be the subject of the lecture, the communication skills of the lecturer, and the value of the lecture to the meeting attendees and the members of the Institute. Klavs Jensen was the recipient in 2018.



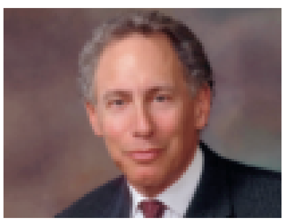
Bill Green receives AIChE's 2019 R.H. Wilhelm Award
The R. H. Wilhelm Award in Chemical Reaction Engineering recognizes an individual's significant and new contribution in chemical reaction engineering. The recipient will have advanced the frontiers of chemical reaction engineering through originality, creativity, and novelty of concept or application.

Paula Hammond elected to NAS, receives AIChE Margaret H. Rousseau Pioneer Award
Hammond is among the 100 new members and 25 foreign associates elected to the National Academy of Sciences on April 30, 2019. Membership to the National Academy of Sciences is considered one of the highest honors that a scientist or engineer can receive. Current membership totals approximately 2,380 members and nearly 485 foreign associates.

The Rousseau Award is presented to a woman member of AIChE who has made significant contributions to chemical engineering research or practice - in academic, industrial, or government settings - over the course of her career. The candidate's contributions may include a component of service, mentorship or leadership in raising the visibility of women engineers and paving the way for other women to have a greater impact in chemical engineering. The award honors the memory of Dr. Margaret Hutchinson Rousseau;

the first woman to earn a PhD in chemical engineering from MIT, the first woman member of AIChE, the first female AIChE Fellow, and the first woman to receive AIChE's Founders Award.

Heather Kulik receives *The Journal of Physical Chemistry* and PHYS Division Lectureship Award
This Lectureship was awarded to Kulik for her groundbreaking work in the development of first-principles and machine learning methodologies for the design of bioinspired inorganic catalysts and to elucidate enzyme mechanisms.



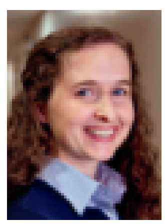
Bob Langer wins 2019 Dreyfus Prize in Chemical Sciences
Langer has been awarded the 2019 Dreyfus Prize for Chemistry in Support of Human Health. Langer is honored for "discoveries and inventions of materials for drug delivery systems and tissue engineering that have had a transformative impact on human health through chemistry." The citation explains that "the drug delivery technologies that he invented have been lauded as the cornerstone of that industry, positively impacting hundreds of millions of people worldwide. The impact and influence of his work is vast, and his papers have been cited in scientific publications more than any other engineer in history."

Karthish Manthiram wins NSF CAREER Award, ACS PRF Award, 3M Non-Tenured Faculty Award
The Faculty Early Career Development (CAREER) Program offers the National Science Foundation's most prestigious awards in support of early-career faculty who have the potential to serve as academic role models in research and education and to lead advances in the mission of their department or organization.

The American Chemical Society's Petroleum Research Fund (ACS PRF) supports fundamental research directly related to petroleum or fossil fuels at nonprofit institutions (generally colleges and universities) in the United States and other countries. Its grants are intended as seed money, to enable an investigator to initiate a new research direction.

The 3M Non-Tenured Faculty Award (NTFA) from 3M's Research and Development Community is in partnership with 3Mgives. The NTFA from 3M recognizes excellent junior faculty members who have been nominated by 3M researchers for their demonstrated record of research, experience, and academic leadership.

Brad Olsen receives AIChE Owens Corning Early Career Award
The Owens Corning Early Career Award recognizes outstanding independent contributions to the scientific, technological, educational or service areas of materials science and engineering. The recipient must be less than 40 years old, and has displayed outstanding materials-related work in discovery, research, process or product development, education, and/or service.



Hadley Sikes and Will Tisdale earn tenure
"The tenured faculty in this year's cohort are a true inspiration," said Anantha Chandrakasan, dean of the School of Engineering. "They have shown exceptional dedication to research and teaching, and their innovative work has greatly advanced their fields."

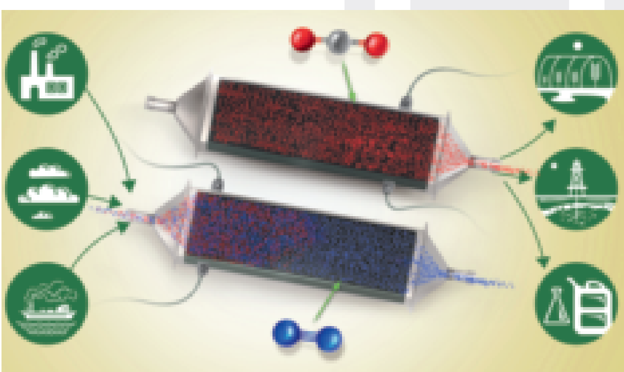
Michael Strano wins AIChE Andreas Acrivos Award
In honor of one of the chemical engineering profession's most influential leaders and one of the great fluid dynamacists of the 20th century, the American Institute of Chemical Engineers (AIChE) has renamed the Professional Progress Award the Andreas Acrivos Award for Professional Progress in Chemical Engineering. Martin Bazant was the previous winner of this award. X

Research Highlights

Hatton Lab develops a new way to remove carbon dioxide from air

A new way of removing carbon dioxide from a stream of air could provide a significant tool in the battle against climate change. The new system can work on the gas at virtually any concentration level, even down to the roughly 400 parts per million currently found in the atmosphere. Most methods of removing carbon dioxide from a stream of gas require higher concentrations, such as those found in the flue emissions from fossil fuel-based power plants. A few variations have been developed that can work with the low concentrations found in air, but the new method is significantly less energy-intensive and expensive, the researchers say.

The technique, based on passing air through a stack of charged electrochemical plates, is described in a new paper in the journal *Energy and Environmental Science*, by MIT postdoc Sahag Voskian, who developed the work during his PhD, and T. Alan Hatton, the Ralph Landau Professor of Chemical Engineering.



A flow of air or flue gas (blue) containing carbon dioxide (red) enters the system from the left. As it passes between the thin battery electrode plates, carbon dioxide attaches to the charged plates while the cleaned airstream passes on through and exits at right.

Hatton Lab's new process could make hydrogen peroxide available in remote places

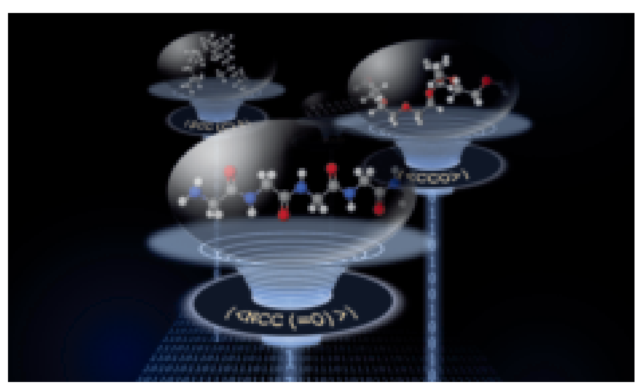
Hydrogen peroxide, a useful all-purpose disinfectant, is found in most medicine cabinets in the developed world. But in remote villages in developing countries, where it could play an important role in health and sanitation, it can be hard to come by.

Now, a process developed at MIT could lead to a simple, inexpensive, portable device that could produce hydrogen peroxide continuously from just air, water, and electricity, providing a way to sterilize wounds, food-preparation surfaces, and even water supplies. The new method is described in the journal Joule in a paper by MIT students Alexander Murray, Sahag Voskian, and Marcel Schreier and MIT professors T. Alan Hatton and Yogesh Surendranath.

Olsen Lab's notation system allows scientists to communicate polymers more easily

Having a compact, yet robust, structurally-based identifier or representation system for molecular structures is a key enabling factor for efficient sharing and dissemination of results within the research community. Such systems also lay down the essential foundations for machine learning and other data-driven research. While substantial advances have been made for small molecules, the polymer community has struggled in coming up with an efficient representation system.

For small molecules, the basic premise is that each distinct chemical species corresponds to a well-defined chemical structure. This does not hold for polymers. Polymers are intrinsically stochastic molecules that are often ensembles with a distribution of chemical structures. This difficulty limits the applicability of all deterministic representations developed for small molecules. In a paper published Sept. 12 in *ACS Central Science*, researchers at MIT, Duke University, and Northwestern University report a new representation system that is capable of handling the stochastic nature of polymers, called BigSMILES.



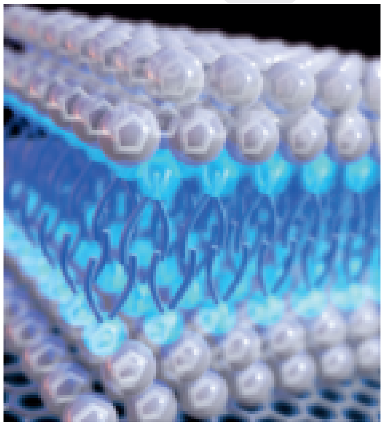
In BigSMILES, polymeric fragments are represented by a list of repeating units enclosed by curly brackets. The chemical structures of the repeating units are encoded using normal SMILES syntax, but with additional bonding descriptors that specify how different repeating units are connected to form polymers. This simple design of syntax would enable the encoding of macromolecules over a wide range of chemistries.

Anderson Lab's delivery system can make RNA vaccines more powerful

Vaccines made from RNA hold great potential as a way to treat cancer or prevent a variety of infectious diseases. One of the challenges to creating RNA vaccines is making sure that the RNA gets into the right immune cells and produces enough of the encoded protein. Additionally, the vaccine must stimulate a strong enough response that the immune system can wipe out the relevant bacteria, viruses, or cancer cells when they are subsequently encountered.

MIT chemical engineers have now developed a new series of lipid nanoparticles to deliver such vaccines. They showed that the particles trigger efficient production of the protein encoded by the RNA, and they also behave like an "adjuvant," further boosting the vaccine effectiveness. In a study of mice, they used this RNA vaccine to successfully inhibit the growth of melanoma tumors.

Hatton Lab's new type of electrolyte could enhance supercapacitor performance



Large anions with long tails (blue) in ionic liquids can make them self-assemble into sandwich-like bilayer structures on electrode surfaces. Ionic liquids with such structures have much improved energy storage capabilities.

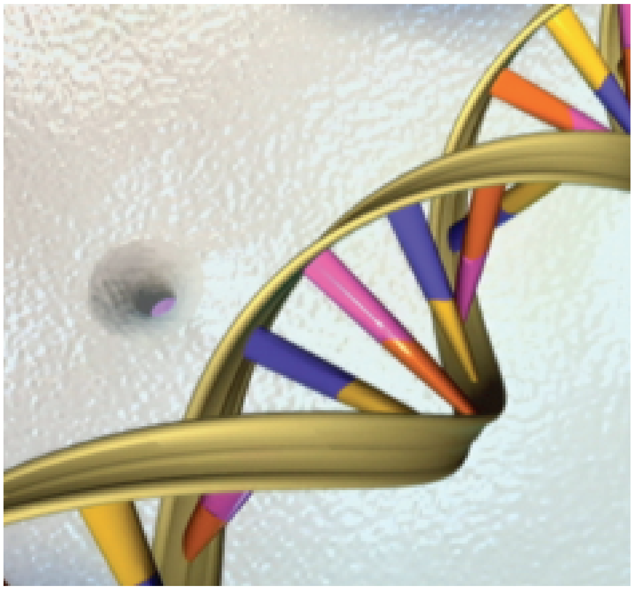
Supercapacitors, electrical devices that store and release energy, need a layer of electrolyte — an electrically conductive material that can be solid, liquid, or somewhere in between. Now, researchers at MIT and several other institutions have developed a novel class of liquids that may open up new possibilities for improving the efficiency and stability of such devices while reducing their flammability.

For decades, researchers have been aware of a class of materials known as ionic liquids — essentially, liquid salts — but this team has now added to these liquids a compound that is similar to a surfactant, like those used to disperse oil spills. With the addition of this material, the ionic liquids "have very new and strange properties," including becoming highly viscous, says MIT postdoc Xianwen Mao PhD '14, the lead author of the paper. "It's hard to imagine that this viscous liquid could be used for energy storage," Mao says, "but what we find is that once we raise the temperature, it can store more energy, and more than many other electrolytes."

The Doyle Lab untangles DNA knots

Just like any long polymer chain, DNA tends to form knots. Using technology that allows them to stretch DNA molecules and image the behavior of these knots, MIT researchers have discovered, for the first time, the factors that determine whether a knot moves along the strand or "jams" in place.

"People who study polymer physics have suggested that knots might be able to jam, but there haven't been good model systems to test it," says Patrick Doyle, the Robert T. Haslam Professor of Chemical Engineering and the senior author of the study. "We showed the same knot could go from being jammed to being mobile along the same molecule. You change conditions and it suddenly stops, and then change them again and it suddenly moves." The findings could help researchers develop ways to untie DNA knots, which would help improve the accuracy of some genome sequencing technologies, or to promote knot formation.



DNA Double Helix

Doyle Lab's "nanoemulsion" gels offer new way to deliver drugs through the skin

MIT chemical engineers have devised a new way to create very tiny droplets of one liquid suspended within another liquid, known as nanoemulsions. Such emulsions are similar to the mixture that forms when you shake an oil-and-vinegar salad dressing, but with much smaller droplets. Their tiny size allows them to remain stable for relatively long periods of time.

The researchers also found a way to easily convert the liquid nanoemulsions to a gel when they reach body temperature (37 degrees Celsius), which could be useful for developing materials that can deliver medication when rubbed on the skin or injected into the body. "The pharmaceutical industry is hugely interested in nanoemulsions as a way of delivering small molecule therapeutics. That could be topically, through ingestion, or by spraying into the nose, because once you start getting into the size range of hundreds of nanometers you can permeate much more effectively into the skin," says Patrick Doyle, the Robert T. Haslam Professor of Chemical Engineering and the senior author of the study.

MIT chemical engineers have devised a way to convert liquid nanoemulsions into solid gels. These gels (red) form almost instantaneously when drops of the liquid emulsion enter warm water.

Rutledge Lab gets the oil out of water

Oil and water are famously reluctant to mix fully together. But separating them completely — for example, when cleaning up an oil spill or purifying water contaminated through fracking — is a devilishly hard and inefficient process that frequently relies on membranes that tend to get clogged up, or "fouled."

A new imaging technique developed at MIT could provide a tool for developing better membrane materials that can resist or prevent fouling. Cleaning up oily wastewater is necessary in many industries, including petroleum refining, food processing, and metal finishing, and the untreated waste can be damaging to aquatic ecosystems. Methods of removing oily contaminants vary, depending on the relative amounts of oil and water and the sizes of the oil droplets. When the oil is emulsified, the most efficient cleanup method is the use of membranes that filter out the tiny oil droplets, but these membranes quickly get fouled by the droplets and require time-consuming cleaning.

But the fouling process is very hard to observe, making it difficult to assess the relative advantages of different materials and architectures for the membranes themselves. The new technique developed by the MIT team could make such evaluations much easier to carry out, the researchers say.

Swan Lab goes from micro to macro

From the perspective of a chemical engineer, particulate gels are the stuff of modern life. These materials, in which small pieces of one kind of substance are suspended or distributed within another, can be found in such construction products as concrete, inks, and paints; foods like cheese, yogurt, and ice cream; and in a range of cosmetic- and health-related staples including shampoo, toothpaste, and vaccines. In sum, says James W. Swan, the Texaco-Mangelsdorf Career Development Professor in Chemical Engineering, "a massive variety of real-world, everyday things bear particles."

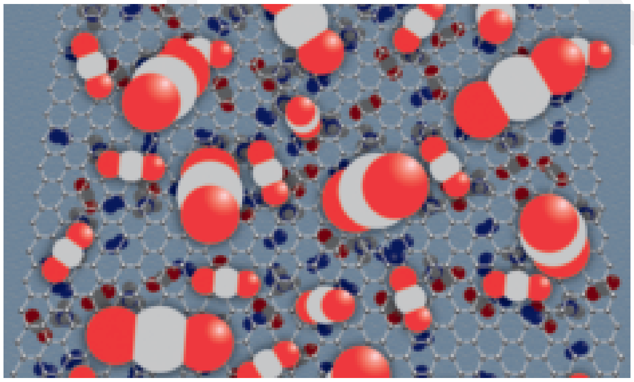
Many of these ubiquitous gels, creams, emulsions, and compounds evolved through "trial-and-error experimentation," says Swan. Engineering such materials often proves to be a prolonged and sometimes inefficient hit-or-miss process. But now Swan and collaborators from other universities have devised a framework that will help guide the design of new materials involving such particulate compounds. An account of their research, which began in 2015, appears in the May 20 2019 issue of Nature Communications.

Smith Lab develops greener, more efficient natural gas filtration

Natural gas and biogas have become increasingly popular sources of energy throughout the world in recent years, thanks to their cleaner and more efficient combustion process when compared to coal and oil. However, the presence of contaminants such as carbon dioxide within the gas means it must first be purified before it can be burnt as fuel.

Traditional processes to purify natural gas typically involve the use of toxic solvents and are extremely energy-intensive. As a result, researchers have been investigating the use of membranes as a way to remove impurities from natural gas in a more cost-effective and environmentally friendly way, but finding a polymer material that can separate gases quickly and effectively has so far proven a challenge.

Now, in a paper published recently in the journal Advanced Materials, researchers at MIT describe a new type of polymer membrane that can dramatically improve the efficiency of natural gas purification while reducing its environmental impact.



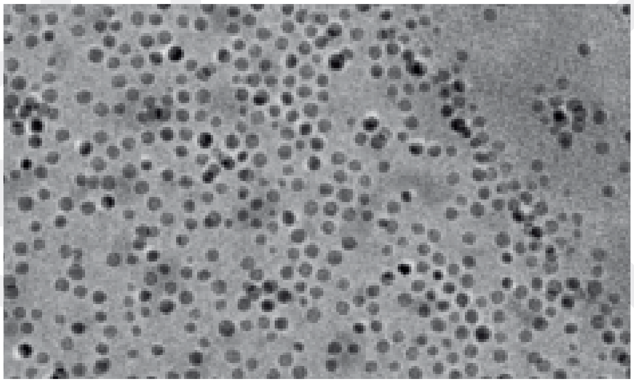
MIT researchers have developed a new polymer membrane that can dramatically improve the efficiency of natural gas purification, while reducing its environmental impact.

Manthiram Lab shrinks the carbon footprint of a chemical in everyday objects

The biggest source of global energy consumption is the industrial manufacturing of products such as plastics, iron, and steel. Not only does manufacturing these materials require huge amounts of energy, but many of the reactions also directly emit carbon dioxide as a byproduct.

In an effort to help reduce this energy use and the related emissions, MIT chemical engineers have devised an alternative approach to synthesizing epoxides, a type of chemical that is used to manufacture diverse products, including plastics, pharmaceuticals, and textiles. Their new approach, which uses electricity to run the reaction, can be done at room temperature and atmospheric pressure while eliminating carbon dioxide as a byproduct.

"What isn't often realized is that industrial energy usage is far greater than transportation or residential usage. This is the elephant in the room, and there has been very little technical progress in terms of being able to reduce industrial energy consumption," says Karthish Manthiram, an assistant professor chemical engineering and the senior author of the new study. **X**



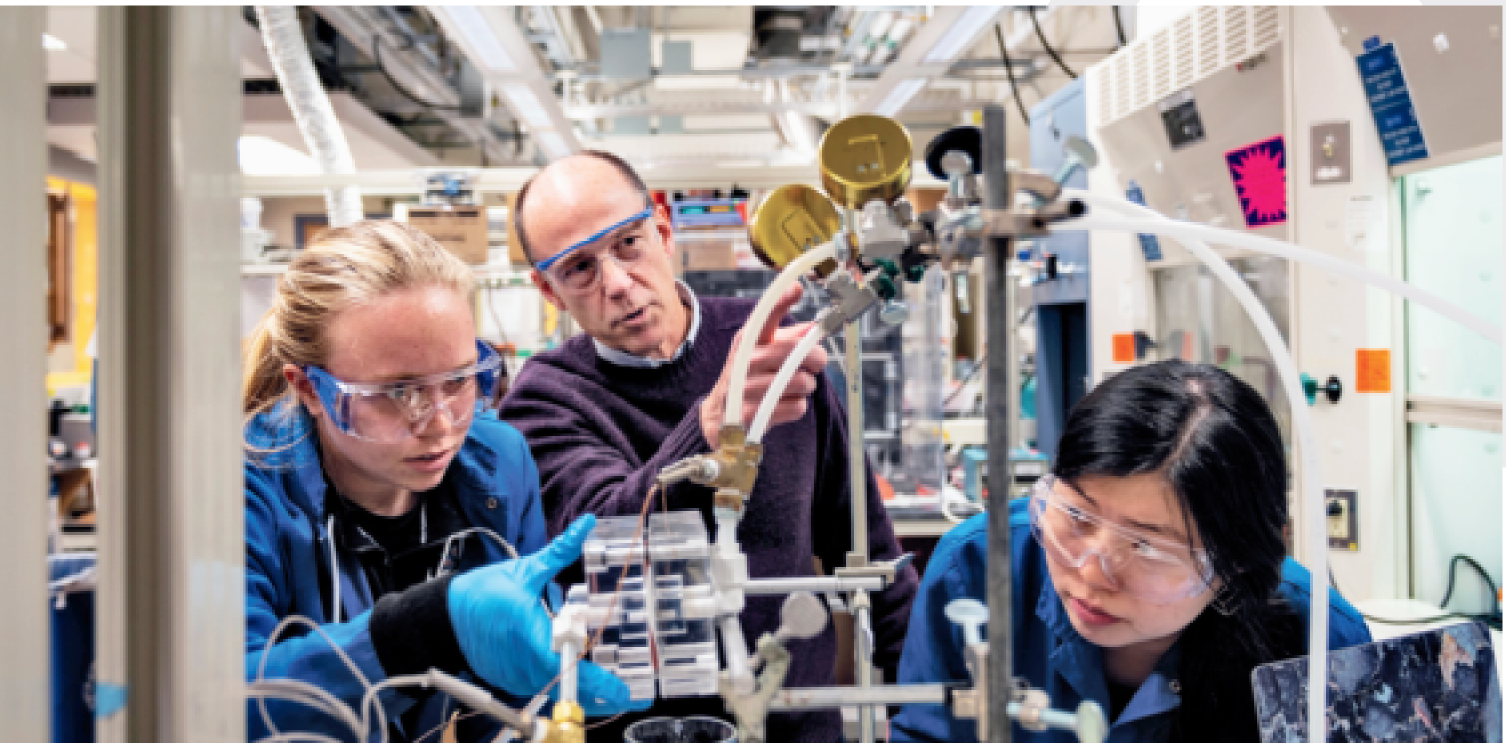
MIT researchers used these manganese oxide nanoparticles to catalyze the breakdown of water and the subsequent incorporation of oxygen into useful compounds called epoxides.

For more information on these and other stories, go to cheme.mit.edu/news

Making it real

Students in a cross-disciplinary projects course are working on real-world engineering problems posed by companies and MIT research labs.

Emily Makowski, School of Engineering



Professor Gregory Rutledge advises two students in 10.26/27/29 (Chemical Engineering/Energy/Biological Engineering Projects Laboratory). (Credit: Lillie Paquette)

Cloudy beige liquid swirls inside a large bioreactor resembling a French press as Jenna Ahn examines small flasks nearby. The lab where Ahn is working, in the subbasement of Building 66, has the feel of a beehive. She's part of one of nine teams of undergraduates huddling in groups at their benches. Every now and then, someone darts off to use a larger piece of equipment among the shakers, spectrometers, flasks, scales, incubators, and bioreactors lining the walls.

These students aren't practicing routine distillations or titrations set up by an instructor. Each team of three or four is trying to solve a problem that doesn't yet have an answer. In 10.26/27/29 (Chemical Engineering/Energy/Biological Engineering Projects Laboratory), students are focused on data-driven, applied research projects. They work on engineering problems posed by companies and by research labs from across the Institute, with the goal of finding solutions that can be applied to the real world.

Ahn, a junior majoring in chemical and biological engineering, and her teammates are studying acid whey, a byproduct of cheese and yogurt. Although whey has nutritional value, it is often treated as a waste product, and its disposal can remove oxygen from waterways and kill aquatic life. While it can be purified and treated like wastewater, the process is expensive.

Ahn's team is using genetically engineered yeast to break down whey into nutritious components like sugars and omega-3 fatty acids, which could then be introduced back into the food chain. After combining the yeast with the whey, the team regularly checks dissolved oxygen and pH levels and monitors whether the yeast is breaking down the whey into its components. "This could be turned into a component of animal feed for cows and other animals," says Ahn, gesturing to the swirling the mixture in her flask.

Fundamentals in action

Gregory Rutledge, the Lammot du Pont Professor of Chemical Engineering, has been the instructor in charge of 10.26/27/29 (Chemical Engineering/Energy/Biological Engineering Projects Laboratory) for about five years. The excitement among the course's students stems from the knowledge that they are directly contributing to advancing technology, he says. "It's a great motivator. They may have gotten fundamentals in their classes, but they may not have seen them in action."

The course has existed in its current form for about 30 years, Rutledge estimates. Its chemical engineering, biological engineering, and energy-related projects appeal to a wide variety of interests. Students are given project descriptions at the beginning of the semester and have flexibility in their choices.

In the current format, students give presentations on their research progress throughout the semester and are evaluated by the 10.26/27/29 professors and their peers. At the end of the term, final presentations are judged by faculty from the entire Department of Chemical Engineering during a project showcase.

The competitive element, Rutledge says, is just one part of how the course has changed over time. "It has evolved toward this organically, as we figure out what students need to know and how to best get that to them."

Each year, the focuses of the students' projects change. Two of this year's teams are working in collaboration with Somerville, Massachusetts, startup C16 Biosciences, trying to use yeast to produce a sustainable alternative to palm oil. The production of palm oil, which is primarily used for culinary and cosmetic purposes, is a leading cause of deforestation.

"We're trying to increase production of saturated fat sustainably," explains Kaitlyn Hennacy, a junior majoring in chemical engineering. "This doesn't require cutting down rainforests and could be a substitute in many applications." Hennacy is examining a cuvette of yellow liquid in which there is a collection of bright orange blobs. The blobs' color is a carotenoid pigment produced as a byproduct during the process. Her team is using seven different solvents, such as hexane and pentane, to extract a palm oil alternative from the yeast.

"It's the intersection of an energy-related project and a consumer project," says Carlos Sendao, one of Hennacy's teammates and a fellow chemical engineering major. "This is a challenge I knew to take." Sendao is going to continue research on this project over the summer through the Undergraduate Research Opportunities Program (UROP) and the MIT Energy Initiative.

Left to right: Sebastian Esquivel, Jenna Ahn, and Crystal Chen break down whey, normally a byproduct, into components for use in animal feed. (Credit: Lillie Paquette)

Kaitlyn Hennacy (left) and Liruonong "Taotao" Zhang are part of a group using yeast to make a sustainable palm oil alternative. (Credit: Lillie Paquette)

Life lessons

Every year Rutledge is impressed with how much students learn and grow over the course of the semester. The problems they're tackling aren't easy, and working in teams presents challenges as students navigate the dynamics of group work.

"They're also learning a lot about life. They're probably going to run into something in the future — whether it's a boss, a team member, or a piece of lab equipment — that doesn't work in the way they expect," he says. "We try to give the students the tools if or when they come across this. And when they give those final presentations, you can see they really have evolved as engineers," he adds.

The approach seems to be effective, says Rutledge. "People will come back one, two, three years later when they're working," he says. "They say, 'I learned so much. This is what I actually do.'" X

Cleaning up hydrogen peroxide production

Solugen's engineered enzymes offer a biologically inspired method for producing the chemical.

Zach Winn, MIT News Office

The large factories that have historically manufactured all of the world's hydrogen peroxide have new, microscopic competitors: altered protein molecules called enzymes.

Certain enzymes, which quicken the pace of chemical reactions, have long been known to work with hydrogen peroxide in various biological systems. But translating that knowledge into a biological-based way to create hydrogen peroxide has proven difficult — until recently.

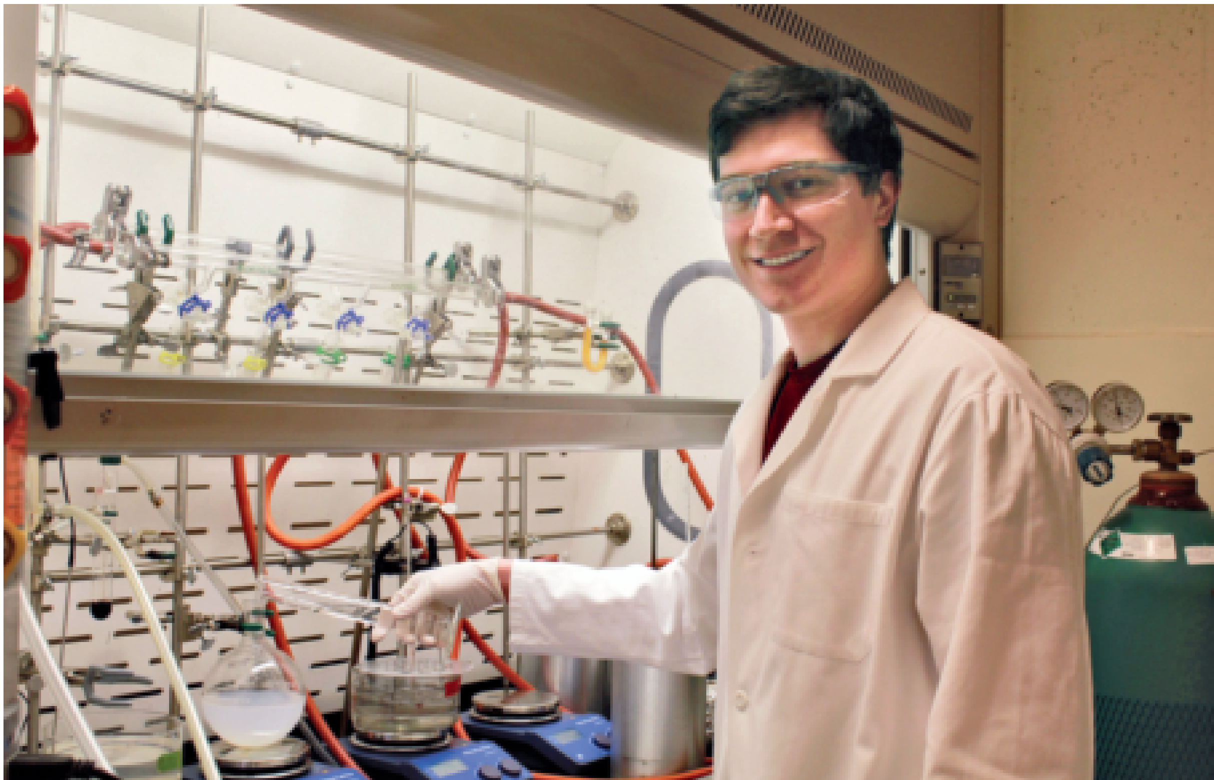
For the past few years, the startup Solugen, which was co-founded by an MIT alumnus, has been producing hydrogen peroxide by combining genetically modified enzymes with organic compounds like plant sugars. The reaction creates bio-based hydrogen peroxide as well as organic acids, and the company says this method is cheaper, safer, and less toxic than traditional processes.

Solugen currently has two pilot facilities in Texas that produce more than 10 tons of hydrogen peroxide per month, with a much larger site opening next summer. The technology has the potential to reduce the carbon footprint of an extremely common chemical used for a host of consumer and industrial applications.

Science companies like Solugen are often started by researchers who have spent years studying a specific problem. Their success often hinges on securing government grants or corporate partnerships. But Solugen has a much more colorful history.

The company can attribute its success to research into pancreatic cancer, a Facebook group of float spa enthusiasts, a fruitful splurge at Home Depot, and the emergence of several fields that make Solugen's solution possible.

Sean Hunt SM '13 PhD '16 as a graduate student in the MIT Chemical Engineering Department in 2014



Solugen's proprietary process for producing hydrogen peroxide uses modified enzymes and inexpensive compounds like sugar. It is currently being used in two pilot facilities that create more than 10 tons of the chemical every day. (Credit: Image courtesy of Solugen)

Getting by with help from Facebook friends

Solugen co-founder Gaurab Chakrabarti was in medical school studying pancreatic cancer in 2015 when he discovered an enzyme in cancer cells that could function in extremely high concentrations of hydrogen peroxide.

The enzyme required another expensive chemical to be useful in reactions, so Chakrabarti partnered with Sean Hunt SM '13 PhD '16, whom he'd befriended while attending medical school with Hunt' wife. Hunt was studying more traditional chemical processing methods for his PhD when Chakrabarti showed him the enzyme.

"My background is not in biotech, so I'm kind of the recovering biotech skeptic," Hunt says. "I learned about enzymes in school, and everyone knew how active and selective they were, but they were just so unstable and hard to manufacture."

Using computational protein design methods, Hunt and Chakrabarti were able to genetically modify the enzyme to make it produce hydrogen peroxide at room temperature when combined with cheap organic compounds like sugar.

Soon after, the founders were finalists in the 2016 MIT $100K pitch competition, earning $10,000. But they still weren't sure the technology was worth pursuing.

Then they were contacted by a Facebook group of float spa enthusiasts. Float spas suspend people in salty waters while shutting out all noise and light to help them achieve sensory deprivation. Hydrogen peroxide is used to keep float spa waters clean.

"There's about 400 float spas in the U.S., and they're all on one Facebook group, and one owner saw our MIT $100K pitch video and shared it to the Facebook group," Hunt explains. "That's really what made us continue Solugen that summer. Because we were contacted by these float spa owners saying, 'This is how much we pay for peroxide. If you guys can make it, we'll buy it.'"

Emboldened, the founders rented cheap lab space in Dallas and sent one of their early enzyme designs to a protein manufacturer in China. Then Hunt spent $7,000 at Home Depot to create a pilot reactor he describes as "this little PVC bubble column."

Running out of money, the founders bought 55 gallon drums of sugar and ran them through the reactor with their enzyme, watching triumphantly as organic acids and hydrogen peroxide came out the other end. The founders began selling all the peroxide they could produce, sometimes sleeping on the floor to keep the reactor running through the night. By December of 2016, they were making $10,000 a month selling pails of peroxide to the float spa community.

The company used its PVC bubble reactor until the summer of 2017, when they built a fully automated reactor capable of producing 10 times more hydrogen peroxide. That's when they moved into the oil and gas industry.

A big, toxic problem

As companies pump oil and gas out of the ground, they generate large amounts of contaminated salt water that needs to be treated or disposed of. Billions of gallons of such water are produced each month in the U.S. alone. Hydrogen peroxide can be used in the treatment process, but Hunt says the traditional methods for creating hydrogen peroxide leave a large carbon footprint associated with the constant venting of the working solution.

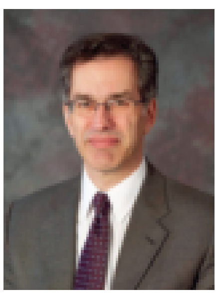
"What I really love about this is it's a true environmental crisis that I think we're making a big difference on," Hunt says, noting other chemicals used to treat wastewater are extremely toxic. X

Alumni Highlights

For more information on these and other stories, go to cheme.mit.edu/news/.

Professor **Monty Alger '78 SM '78** has been named AIChE president-elect. Alger has more than 30 years of experience in the chemical and energy industries. Prior to his current position as professor at Penn State, he was the senior vice president of research and development at Myriant Corp. and before that he was the vice president and chief technology officer with Air Products and Chemicals, Inc. He also spent 23 years with General Electric (GE), where he led technology development at the Global Research Center of GE Plastics, and was the general manager of technology for the Advanced Materials business. Prior to GE, he was director of the MIT Chemical Engineering Practice School Station at GE Plastics.

Alger is a member of the National Academy of Engineering and has served on advisory boards for several universities and companies. He served on AIChE's board of directors from 2010 to 2012, and on the AIChE Finance Committee.



Elliot Chaikof, MD, PhD '89, Chair of the Department of Surgery and Chief of Surgery at Beth Israel Deaconess Medical Center (BIDMC), has received the American Surgical Association's 2019 Flance-Karl Award. Each year, the Association's Flance-Karl Award Committee recognizes one surgeon in the United States who has made seminal contributions in translational research that have applications to clinical surgery of any specialty. Past recipients of the award, considered one of the most prestigious recognitions of scientific achievement in the world, include M. Judah Folkman, MD, Francis D. Moore Sr., MD, and Steven A. Rosenberg, MD, PhD.

Chaikof has led a multitude of research efforts that have advanced the development of engineered living tissues, implantable devices, and artificial organs, as well as cell-based therapies. Most recently, his work has focused on drug discovery, in collaboration with medicinal and computational chemists, to develop more effective treatments for atherosclerosis, venous thrombosis, metabolic syndrome and inflammatory bowel disease.

Jeffrey Cleland PhD '91 has been appointed to the board of directors for Exicure, Inc. Cleland, co-founder and executive chairman of Orpheris, has founded start-ups and built businesses. Cleland received his B.S. in chemical engineering from University of California Davis. He has more than 20 years of industry experience in drug development from discovery stage to approval for small molecules, peptides and proteins. Exicure, Inc. is a clinical-stage biotechnology company developing therapeutics for immuno-oncology, inflammatory diseases and genetic disorders based on our proprietary Spherical Nucleic Acid, or SNA technology.

William Feehery PhD '98 has become the new CEO of Certara. Dr. Feehery joins Certara from DuPont, where he has served since 2013 as president of DuPont Industrial Biosciences, a $2.2 billion global biotechnology business which experienced significant growth and profitability under his leadership. In that role, he had full P&L responsibility for 3,000 people, including 500 R&D staff, 20 manufacturing plants, and worldwide marketing and sales across multiple markets. He joined DuPont in 2002 and has prior experience in venture capital and as a consultant for the Boston Consulting Group. Dr. Feehery also serves as a board member for West Pharmaceutical Services, a manufacturer of packing components and delivery systems for pharmaceutical, biotech and medical device companies. Feehery holds both a PhD in chemical engineering and an MBA from MIT. He was a Churchill Scholar at Cambridge University, and received his BSE in chemical engineering from the University of Pennsylvania. His doctorate, awarded while he was the recipient of a National Science Foundation Fellowship, involved developing software and mathematical methods for modeling complex systems. X

MIT Chemical Engineering welcomes three new professors

We are pleased to announce three new assistant professors joining the department, two during the summer of 2019, and one in 2020. Our faculty, staff and students look forward to working with them as they bring their knowledge and curiosity in the areas of synthetic biology, machine learning, and electrochemical biotechnology and sensing.

For more on these and all our faculty, go to cheme.mit.edu/people/

Connor W. Coley

Research interests: Molecular discovery, machine learning, organic synthesis

Connor is already very familiar with the department, as he is graduate student in the labs of MIT professors Bill Green and Klavs Jensen. His future research will work toward a new paradigm of computational assistance for molecular discovery through an interdisciplinary approach combining chemistry, chemical engineering, and computer science in close partnership with experts in application domains such as chemical biology and human health. He's been named a DARPA Riser, one of C&EN's Talented 12, and one of Forbes 30 under 30: Healthcare. Connor will join us in August of 2020.

Ariel L. Furst

Research interests: Diagnostic devices, Biotechnology

Ariel was born and raised in St. Louis, MO. She received her BS in Chemistry from University of Chicago, during which time she worked with Shelley Minteer at Saint Louis University and Stephen B. H. Kent. She completed her PhD in the lab of Jacqueline Barton at the California Institute of Technology and is currently an Arnold O. Beckman Postdoctoral Research at the University of California, Berkeley in the lab of Matthew Francis. Ariel joined us in August of 2019.

Katie E. Galloway

Research interests: Molecular systems biology, synthetic biology, stem cell engineering, regenerative medicine, epigenetics

Kate has engineered systems for dynamic behaviors across multiple scales, from the molecular design of noncoding RNA devices to optimization of large transcriptional networks. Her graduate work in the Christina Smolke lab at Caltech, constructing synthetic gene circuits to regulate cellular decision-making, was published as a first author research article in Science. As a postdoc, Kate examined the molecular processes that direct cell fate during cellular reprogramming in the laboratory of Dr. Justin Ichida, Assistant Professor in the Department of Regenerative Medicine at USC. Her lab at MIT will focus on developing integrated gene circuits and elucidating the systems-level principles that govern complex cellular behaviors. The ultimate goal of her research is to leverage synthetic biology to transform how we understand cellular transitions and engineer cellular therapies. Kate joined us in July of 2019. X

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Thank you to everyone who has supported us throughout the year.

Every effort has been made to ensure the accuracy of this list. Please direct corrections to Melanie Kaufman, editor, at melmils@mit.edu.

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Zhihong Wang
Robert A Ware
Douglass J Warner
Robert P Webb
Alfred E Wechsler
Christopher P Wedig
James C Wei
Maurice W Wei
Randy D Weinstein
Harold N Wells
Martin A Welt
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Alyse Wu
Michelle H Wu
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Reginald S Yeung
Kai W Young
Charles R Youngson Jr
Maggy S Yu
Roger L Yu
Meng Yi C Yue
Michael Zeltkevic
Jingqing Zhang
Lei Zhang
Xinjin Zhao
Yizu Zhu
Allyn J Ziegenhagen
Andrew L Zydney

In Memoriam

Professor Emeritus Marcus Karel

During a symposium in his honor on May 16, 2016, Professor Emeritus Marc Karel (center right) receives a plaque from the European Academy of Food Engineering, sponsored by the Institute of Food Technology.

Marcus Karel, food science pioneer and professor emeritus of chemical engineering, dies at 91

A giant in the field of food science and engineering, Karel developed important innovations in food packaging as well as food systems for long-term space travel.

Marcus “Marc” G. Karel PhD ’60, professor emeritus of chemical engineering, died on July 25 at age 91. A member of the MIT community since 1951, Karel inspired a generation of food scientists and engineers through his work in food technology and controlled release of active ingredients in food and pharmaceuticals.

Karel was born in Lvov, Poland (now Lviv, Ukraine) to Cila and David Karel, who ran a small chain of women’s clothing stores in the town. After war arrived in Poland in 1939, the family business was lost, relatives were scattered and disappeared, and the Karels spent the last 22 months of the war in hiding. After the war, Karel and his family eventually emigrated to the United States, where they settled in Newton, Massachusetts, just outside of Boston. Karel completed his bachelor’s degree at Boston University in 1955 and earned his doctorate in 1960 at MIT.

Before Karel started his graduate studies at MIT, he was invited by the head of the former Department of Food Technology to manage the Packaging Laboratory. Here he began his interest in the external and internal factors that influence food stability. In 1961, he was appointed professor of food engineering at MIT in the former Department of Nutrition and Food Science (Course 20), eventually becoming deputy head of the department. When Course 20 (then called Applied Biological Sciences) was disbanded in 1988, Karel was invited to join the Department of Chemical Engineering. After retiring from MIT in 1989, he became the State of New Jersey Professor at Rutgers University from 1989 to 1996, and from 1996 to 2007 he consulted for various government and industrial organizations.

During his academic career at MIT and Rutgers, Karel supervised over 120 graduate students and postdocs. Most of them are now leaders in food engineering. Several of his trainees from industry are now vice presidents of research and development at several companies. Along with his engineering accomplishments, Karel was known for his ability to build and manage successful teams, nurture talent, and create a family environment among researchers.

At the 2011 International Conference for Engineering and Food, Marc Karel (right) receives the ICEF 11 Lifetime Achievement award, recognizing his lifelong contribution and international impact on the progress of food engineering.

Karel was a pioneer in several areas, including oxidative reactions in food, drying of biological materials, and the preservation and packaging and stabilization of low-moisture foods. His fundamental work on oxidation of lipids and stabilization led to important improvements in food packaging. Also, when NASA needed expertise to design food and food systems for long-term space travel, it was Karel's work that formed the platform for many of the enabling developments of the U.S. space program. MIT Professor Emeritus Charles Cooney relates, "When the solution to an important problem required improved analytical techniques, he pioneered the development of the techniques. When the solution required deeper insight into the physical chemistry of foods, he formulated the theoretical framework for the solution. When the solution required identification of new materials and new processes, he was on the front line with innovative technologies. No one has had the impact on the field of food science and engineering as Marc."

Karel earned many recognitions for his work, including a Life Achievement Award from the International Association for Engineering and Food, election to the American Institute of Medical and Biological Engineering, the Institute of Food Technologists (IFT)'s Nicholas Appert Medal (the highest honor in food technology), election to the Food Engineering Hall of Fame, several honorary doctorates, and the one of which he was most proud: the first William V. Cruess Award for Excellence in Teaching from the IFT. The first edition of his co-authored book, "The Physical Principles of Food Preservation," is considered by many to be the "bible" of the field of food stability.

Karel is survived by his wife of almost 61 years, Carolyn Frances (Weeks) Karel; son Steven Karel and daughters Karen Karel and Debra Karel Nardone; grandchildren Amanda Nardone, Kristen Nardone, Emma Griffith, and Bennet Karel; sister Rena Carmel, niece Julia Carmel, and great-nephew David Carmel; Leslie Griffith (mother of Emma and Ben); nephew James Weeks Jr., and niece Sharon Weeks Mancini.

Funeral arrangements were private. Memorial contributions may be made to the American Red Cross. X

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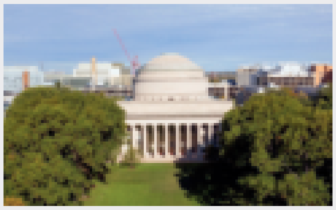
We hope to see you soon!
Save the date:

Friday, March 13, 2020
Alan S. Michaels Distinguished Lectureship in Medical and Biological Engineering

Hongming Chen ScD '97,
Chief Science Officer,
Kala Pharmaceuticals

Friday, March 20, 2020
Graduate Alumni Gathering

For more info and to register, go to alum.mit.edu.



Friday, April 17, 2020
Warren K. Lewis Lectureship

Howard A. Stone, Donald R. Dixon '69 and Elizabeth W. Dixon Professor in Mechanical and Aerospace Engineering, Princeton University

Friday, May 29, 2020:
Current alumni are invited to celebrate our newest round of graduates at the Course X Commencement Reception.

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