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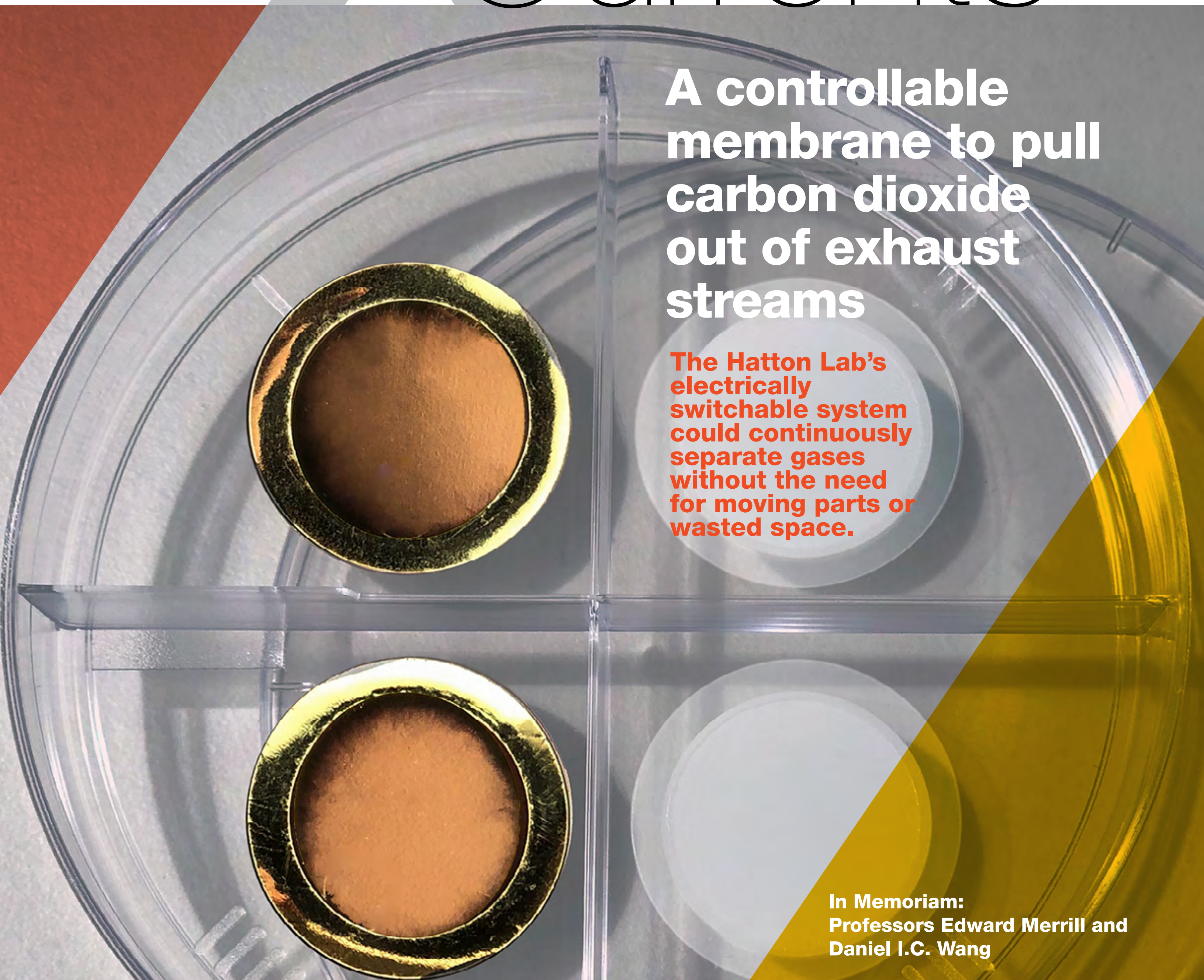
MIT Chemical Engineering Alumni News



A controllable membrane to pull carbon dioxide out of exhaust streams

The Hatton Lab's electrically switchable system could continuously separate gases without the need for moving parts or wasted space.

In Memoriam: Professors Edward Merrill and Daniel I.C. Wang

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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

The disruptions and events of 2020 have brought so many changes and challenges for all of us. I'd like to share with you, our alumni and friends, some of the things we're doing in the Department to face the present challenges, while we continue our current research and education. This balance would not be possible without our outstanding faculty, students, alumni and friends of MIT ChemE.

We are a strong and resilient community: even as we continue to take vital precautions to keep our campus and researchers safe we are at the front line of the fight against the current global pandemic. When the Boston area started to lock down in March, we had researchers immediately take to the lab to work on solutions to help fight the pandemic, while strictly adhering to new and unfamiliar safety protocols and practices. I want to share a quote from the MIT News article that reflects well what was going on in several of our labs:

> *In the lab of Professor J. Christopher Love, a small team was cleared to return to the lab to continue their mission: generating and testing preclinical materials to push new vaccines for Covid-19 to reach the stage of conducting human trials on a much faster timeline than the many years that vaccine development typically takes. "It was like a blitz at the beginning to see if something would work," says Neil Dalvie, a graduate research assistant who's part of the Love Lab's onsite team, together with Andrew Biedermann, Laura Crowell, and Sergio Rodriguez, also graduate research assistants.*
>
> *Everyone else from the lab coordinated from home, via Zoom, phone, and email. Dalvie says it's not the most efficient way to work. Having team members working remotely slows the whole process down, right when the need for speedy development has become most crucial. But the Love Lab got it done.*

They got it done. And we will continue to get it done as we move into 2021 with the momentum of approved vaccines, quicker tests, and a burgeoning understanding of the virus, its composition and its weaknesses.

On a more somber note, I'm sorry to share we recently lost two faculty members who were not only giants of the Chemical Engineering field, but treasured friends and mentors to their colleagues and students: Ed Merrill and Danny Wang.

Both Ed and Danny are especially dear to me: Ed was the lecturer of the key polymer science classes I took as a student at MIT, and I co-taught with him soon after I started as a Professor in the Department. His understanding of the physical chemistry of polymers and ability to convey difficult concepts clearly were unparalleled.

I also consider myself fortunate to have had the chance to experience, for myself, Danny's kindness, his wisdom, and his humor. He always had an uncanny ability to see the big picture of where the biochemical engineering field was going, and the impacts of Danny's research are found in every sector of the biotech and pharmaceutical fields today.

We will work to continue both Ed's and Danny's legacies as we work to innovate through our research and our education. I wish you a safe and enjoyable holiday season and look forward to sharing more news with you soon.

Best regards,

Paula T. Hammond
Department Head

While in Dubai, the students had several opportunities for trips around the city. Here, the team enjoyed dinner at the Global Village.

Greetings from the MIT Practice School

Greetings from the MIT Practice School. What a year!! Our program promotes real-world problem solving, and, as you can imagine, 2020 helped to add a layer of challenge to the already demanding projects our students addressed. I'm proud of our students' work and their ability to be flexible in the face of an unprecedented situation in which on-site participation this summer was not possible, and offer you some information about the projects of this past year and our future plans. We are truly grateful to our corporate sponsors for their enthusiasm and strong support of the Practice School program and students.

Notes from our latest stations are below, and right now station directors Brian Stutts, Mike Sarli, Tom Blacklock, and Doug Harrison, along with Charles Baker and current AIChE president Monty Alger, are working together to create a new IAP course, 10.801 Project Management and Problem Solving in Academia and Industry. This effort is spearheaded by Bob Hanlon, who has proven his leadership through his previous station director position and his management of the centennial celebration of the Practice School. The 10.801 course teaches both soft and hard skills to foster student success through their Practice School experience and the same skills are expected to be valuable for problem-solving in both academic and industrial settings at large. Themes to be covered include career development, project management, leadership, project economics, techniques for problem solving, literature search, safety, professional behavior, and time management. I look forward to sharing in my next letter the outcome of this first offering.

Fall 2019 Practice School Stations

During the fall semester, the Practice School students first went to Shell in Houston, with Doug Harrison as Station Director, and then on to Emirates Global Aluminium (EGA) in Dubai, accompanied by Station Director Brian Stutts. Shell provided six long-term research projects for the MIT teams to address, most of which were in their very preliminary stages. The basis for the work was an environment in which carbon emissions were subject to costs (carbon taxes or other premiums), thereby catalyzing the development of technologies to result in net-negative growth of CO2 concentration in the atmosphere.

At the Dubai station, one team looked into the feasibility of collecting energy from magnetic fields and using it within the manufacturing process. Mathematical modeling was successfully applied to the analysis of bauxite residue processing to identify ways in which a past waste product destined for landfills could be used to augment soil. Other teams focused on identifying ways to manage the dissolved oxygen levels in waste streams so the effluent could be discharged to the sea; optimizing the use of power plant equipment after upgrades; and identifying heat-integration options for the newly commissioned alumina calciner.

Spring 2020 Practice School Stations

The spring stations were at the National Renewable Energy Laboratory (NREL) in Golden, Colorado, (with Mike Sarli as Station Director) and Saint Gobain in Northboro, Massachusetts, under the supervision of Bob Fisher. The NREL station started normally enough in late January, but by the late March, the students were dealing with the ramifications of Covid-19. During the last week, they worked from their lodgings and gave final presentations remotely — our first experience operating in a virtual situation. Projects ranged from designing a continuous flow reactor for a biological reaction to a technical/economic evaluation of several novel processes as possible replacements for fossil fuel-based petrochemicals.

The first session at Saint Gobain consisted of two projects. One focused on developing a more thorough understanding of an existing materials-processing system and the need to evaluate alternative control strategies based on key performance factors. The second was involved with a proof-of-concept investigation requiring the application of new tissue-therapy systems to identify cell characteristics as monitored in their Vue/Life culture bags. The second session extended these projects.

Summer 2020 Practice School Stations

In late spring, I had several conversations with host companies about how we might structure stations in the COVID era. Based on these conversations, the student group participated in virtual summer stations at Schlumberger New Energy and a second station assignment at AstraZeneca. Despite my initial trepidation, both stations were unqualified successes, in no small part due to the dedication of Station Directors Brian Stutts and Tom Blacklock, in addition to the sponsors at both stations.

For Schlumberger New Energy, the students worked on four projects: two focused on carbon footprint reduction in existing processes and two on technical evaluations of carbon-neutral energy opportunities. The students were exceptionally flexible and all four teams met, if not exceeded, their objectives. Within two weeks of station completion, work from two of the four project teams was already being aggressively deployed in the field by Schlumberger.

AstraZeneca readily agreed to a virtual station and supplied the team with company laptops so that they would be fully integrated with the AstraZeneca intranet. There were 12 projects to choose from, all of which were of such high caliber that the director agreed to run the station with five two-person projects. The virtual station was highly productive, and the team found many opportunities to work virtually on presentation skills and socialize together online.

Best regards,

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

MIT ChemE works to fight the COVID-19 pandemic

From diagnostics to vaccines, to treatments for coronavirus and COVID-19, several labs in the Department are directly addressing the current pandemic. Our chemical engineers provide an unparalleled skillset for approaching biomedical problems: almost a third of our faculty are working in areas related to human health. Below are just some of our projects that have been designated by the Institute as critical to the current crisis. You can find more information at https://cheme.mit.edu/covid-19-department-response/.

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indoor-covid-safety.herokuapp.com (COVID-19 Indoor Safety Guideline app)

Martin Z. Bazant is using mathematical models from chemical engineering and epidemiology to develop an appropriate safety guideline for well-mixed indoor spaces. The guideline is parameterized by the latest data for COVID-19 spreading and respiratory aerosol emissions, and made publicly available in an easy-to-use app.

Langer Lab working on several COVID-related projects

Bob Langer is the academic founder and scientific advisor of Moderna, whose vaccine has just received FDA approval.

The lab is also collaborating with New Balance and Brigham and Women's Hospital to advise on fabrication of N95-like masks for healthcare workers. The lab tests the breathability of the newly developed masks according to standard test methods for air permeability of textile fabrics (ASTM D737-96 standard). The team is developing an invisible, on-patient medical record to address the need for accurate medical record keeping in low resource settings (where no centralized database is available) and during disease outbreak/mass vaccination campaigns where large numbers of people are vaccinated in a short period of time and where the movement of large numbers of people hinders accurate disease management.

MIT's Love Lab works to develop Covid-19 vaccine to potentially reach billions

Chris Loves's group has been working on developing ultra-low cost recombinant subunit vaccines which have the potential to be deployed in areas without developed medical infrastructure. Of all the Gates Foundation partners in the space, Chris's group was the first to develop useable vaccine material that demonstrated an immune response, and one of his proteins has been incorporated into a product candidate now in clinical trials with partners in India.

Testing whether uncertified N95 masks are effective

Greg Rutledge has been working on testing mask efficiency and tested the entire N-95 stockpile of the Massachusetts Emergency Management Agency to ensure that they were providing adequate protection to first-responders.

Sikes Lab collaborates with 3M to develop rapid Covid-19 test

Hadley Sikes has been working for years with her team on the technology they're adapting to create a Covid-19 test with rapid results. Moving beyond lab prototypes and into manufacturing the diagnostics on a large scale, however, is new territory. 3M is collaborating with the Sikes Lab to jointly develop the test, including establishing novel processes for scaling it. They will determine whether the test renders highly accurate results within 10 minutes, and if it is feasible to mass manufacture.

Heated face mask that filters and inactivates coronaviruses

Michael Strano and colleagues hope to go one step further with face masks: creating one that inactivates viruses using heat. The researchers aim to build masks that incorporate a heated copper mesh. As the person wearing the mask breathes in and out, air flows repeatedly across the mesh, and any viral particles in the air are slowed and inactivated by the mesh and high temperatures. X

In Memoriam

Edward W. Merrill

Biomaterials pioneer considered "the premier biomedical engineer of the 20th century."

Edward W. Merrill ScD '47, professor emeritus of chemical engineering, died peacefully at his home on August 6, 2020, at the age of 96, surrounded by his children and grandchildren.

"Ed made an indelible mark on each life he touched, professionally and personally. Not only did his research contributions help better the lives of thousands, but his commitment to education and mentorship helped shape a generation of biomedical engineers," said Paula Hammond, David H. Koch (1962) Professor in Engineering and Head of the MIT Chemical Engineering Department, "I experienced it first hand as a student and a co-teacher; he raised the bar for all of us."

Merrill was a founder of the area of biomaterials, and over his 66 year career, he pioneered several fields of bioengineering. In the 1950s and 60s, he was the leading scientist in blood rheology. He investigated the effect of the hematocrit, various plasma proteins, and white blood cells on blood viscosity and flow behavior, and he developed appropriate experimental tools for rheological investigations of blood (including the patented GDM [Gilinson-Dauwalter-Merrill] viscometer) under realistic in-vitro conditions. In the 1960s and 1970s, Merrill was a pioneer in the development of the artificial kidney, analysis of its transport characteristics and optimization of hemodialyzer membranes. In fact, Merrill's pioneering work on artificial kidneys, with Professor Clark Colton PhD '69 and Robert A. Britton ScD '67, led to the development of the first NIH guidelines for artificial kidneys in the 1960s. In the 1960s, 70s and 80s, he pioneered the field of protein/polymer interaction under stagnant and flow conditions and made exceptional contributions in the development of hydrogels as biomaterials, and in ionic or covalent heparinization techniques on polymer surfaces for antithrombogenic materials.

"Professor Merrill was probably the premier biomedical engineer of the 20th century," said Nicholas Peppas ScD '74, the Cockrell Family Regents Chaired Professor at the University of Texas at Austin and advisee of Merrill, "Not only did he develop the fundamentals of the field, and came up with pioneering inventions of blood flow rheometers, non-thrombogenic biomaterials, advanced contact lenses, treatments of the respiratory distress syndrome, and the most successful materials for join replacements, but he also became a superb educator and mentor who directed and advised hundreds if not thousands of biomedically-oriented students of diverse backgrounds and nationalities."

Merrill personally supervised 57 PhD, 62 MS students and 12 postdocs in his career. About 35 of these became professors in engineering, sciences or medicine in academic institutions. About 20 of them became entrepreneurs serving as CEOs or other leaders of the chemical, biomedical or pharmaceutical industries. Merrill and eight of his former students or associates were listed in the 2008 AIChE list of "100 Eminent Chemical Engineers of the Modern Era." Fifty-five of his academic descendants are members of the major Academies now: 28 are National Academy of Engineering (NAE) members, 19 are members of the National Academy of Medicine (NAM), 3 are National Academy of Sciences (NAS) members, and 5 are members of the American Academy of Arts and Sciences (AAAS). Many US and international companies have been founded on his pioneering research ideas by his students and others.

Merrill was elected a member of the AAAS, the NAE, the NAM, and the National Academy of Inventors (NAI). He received the Founders Award of the American Institute of Chemical Engineers (AIChE) in 2000, the Founders Award of the Society for Biomaterials (SFB) in 2003, and the Pierre Galletti Award from the American Institute of Medical and Biological Engineers in 2010. AIChE had also bestowed upon him the 1982 Alpha Chi Sigma Award and the 1993 Charles M. A. Stine Award. In 1990, the SFB awarded him the Clemson Award. At its Centennial Celebration in 2008, AIChE recognized him as one of the "100 Eminent Chemical Engineers of the Modern Era."

Merrill married Genevieve de Bidart (Ginette) on August 19, 1948, in Cambridge, MA. Ginette passed away 7 months earlier on December 20, 2019. They are survived by their daughter Anne and son Frank Merrill, and their grandchildren: James, Sasha and Julia Merrill. Merrill took great pride in his two children and three grandchildren and enjoyed the time he spent with them immensely. Ed was not simply a father and grandfather, but a mentor and inspiration to all who encountered him. His presence and his wisdom will sorely be missed by all whose lives he touched, and he will be greatly missed by his family. The family has already held private services. X

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

In Memoriam

Daniel I.C. Wang

Longtime MIT professor launched the Biotechnology Process Engineering Center and influenced generations of students.

Anne Trafton, MIT News Office

Daniel I.C. Wang, an MIT Institute Professor who was considered one of the founding fathers of the field of biochemical engineering, died Saturday in Cambridge, Massachusetts. He was 84.

During his long career at MIT, Wang contributed to many aspects of biochemical engineering — a field that involves genetically engineering microbes and human cells to produce useful proteins. His research spanned all phases of the process, including fermentation, monitoring and control of bioprocesses, enzyme technology, product purification, and protein folding.

In 1985, Wang was the driving force behind the launch of MIT's Biotechnology Process Engineering Center (BPEC), which was founded as a multidisciplinary research center bringing together faculty from the departments of Biology, Chemistry, and Chemical Engineering.

"Danny's work and impact in the field of biochemical engineering were profound, and led to a major shift in the growth of chemical engineering at the interface with biology," says Paula T. Hammond, the David H. Koch Professor and head of the MIT Department of Chemical Engineering. "He extended chemical engineering concepts to bioreactors and the first efforts in bioprocesses, enzyme technology, and mammalian cell cultures, among many other accomplishments. Chemical engineering has lost a giant, and the department has lost a good friend and incredible mentor to our faculty, researchers, and numerous alumni."

Born in Nanking, China, Wang worked to establish international ties between MIT and universities in other countries, particularly in Asia. He established a joint program in molecular engineering of biological and chemical systems with the National University of Singapore, which became part of the Singapore-MIT Alliance for Research and Technology (SMART).

Wang, who served as the Chevron Professor of Chemical Engineering before being named an Institute Professor, was also known for his dedication to his students. Noubar Afeyan, a former student of Wang's who is now the CEO of Flagship Pioneering and a member of the MIT Corporation, described him as a friend and cherished mentor.

"Danny touched thousands all over the world by inspiring generations of students, industrial collaborators, and fellow professors. He was confident yet humble, tough yet caring, serious yet playful, with an insatiable appetite for good Chinese food. We will miss Danny and work hard to make his legacy proud," Afeyan says.

In recognition of Wang's pioneering research, MIT's Frontiers of Biotechnology Lectureship was renamed for him in 2014. Now known as the Daniel I.C. Wang Lecture, the lectureship honors achievements at the frontiers of biotechnology, and the distinguished scientists and engineers responsible for them.

"Dan Wang's influence as a teacher, mentor, researcher, and friend has been monumental to so many people who have become the leaders in building a biotech industry and biochemical engineering as a profession," says Charles Cooney, the Robert T. Haslam Professor of Chemical Engineering at MIT. "Though saddened by his passing, we celebrate his legacy of unwavering nurturing of students and colleagues to address challenging problems with innovative solutions."

Wang earned two degrees from MIT — a BS in 1959 and an MS in 1961. In 1963, he earned a PhD in chemical engineering from the University of Pennsylvania. He joined the MIT faculty in 1965 and was named an Institute Professor, MIT's highest faculty honor, in 1995. He received numerous honors and awards, including the Amgen Biochemical Engineering Award in 1995 and the William H. Walker Award from the American Institute of Chemical Engineers in 1994. He was also a member both of the National Academy of Engineering and the American Academy of Arts and Sciences.

In 2019, the American Institute of Chemical Engineers established an award in his honor — the D.I.C. Wang Award for Excellence in Biochemical Engineering. The award is given annually and "recognizes individuals for their contributions to the field and to the practice of biochemical engineering through their position in industry or academia as exemplified by Professor Wang in his 50 years of contributions," according to the AIChE.

Wang also contributed to national efforts in biotechnology, as chair of the Membership Committee of the National Academy of Engineering, a member of the National Biotechnology Policy Board at the National Institute of Health, a member of the National Research Council Committee on Bioprocess Engineering, a member of the National Research Council Committee on Biotechnology, and a member of the Board of Biology of the National Research Council.

He also co-authored five books, published more than 250 papers, and was awarded 15 patents.

Wang is survived by his wife, Victoria; his son, Keith; his daughter-in-law Katherine; his two granddaughters, Veronica and Emily; his sister, Judy, and her family; and his sister-in-law, Cecile. Plans for a memorial will be announced at a later date. X

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

Faculty Highlights

Bob Armstrong receives AIChE 2020 Founders Award, elected to AAAS
AIChE's Founders Award for Outstanding Contributions to the Field of Chemical Engineering recognizes outstanding contributions in the chemical engineering field. The award is presented to a member of AIChE who has had an important impact on chemical engineering and whose achievements, either specific or general, have advanced this profession in any of its aspects. The recipient should have a long and distinguished record of service to the profession, including both technical and professional activities.

One of the nation's most prestigious honorary societies, the American Academy of Arts and Sciences (AAAS) is also a leading center for independent policy research. Members contribute to academy publications, as well as studies of science and technology policy, energy and global security, social policy and American institutions, the humanities and culture, and education.

Fikile Brushett earns NOBCChE Lloyd N. Ferguson Young Scientist Award, and Tenure
The National Organization for the Professional Advancement of Black Chemists and Chemical Engineers (NOBCChE) has selected Associate Professor Fikile Brushett as the 2020 recipient of the Lloyd N. Ferguson Young Scientist Award for Excellence in Research. This award is granted to a young scientist who has demonstrated technical excellence and documented contributions to their field. It also recognizes dedication shown to research and to the community. Brushett received the award at NOBCChE's Annual Conference on Sept. 25, and is scheduled to give the Lloyd Ferguson Lecture on May 11, 2021, as part of its Master Scientist Series.

Bob Langer wins 2020 Maurice Marie-Janot Award
The Maurice-Marie Janot Award, given by the International Society for Drug Delivery Sciences and Technology, recognizes an individual researcher whose pioneering work has a groundbreaking impact in the fields of pharmaceutics, biopharmaceutics and pharmaceutical technology. The Jury is composed of 70 scientists from all over the world, who are known for their relevant contributions to the pharmaceutical sciences.

Karthish Manthiram receives several recognitions
MIT Teaching with Digital Technology Award: In its fifth year, the Teaching with Digital Technology Awards are student-nominated awards for instructors who have effectively used digital technology to improve teaching and learning at MIT. The goal is to recognize instructors for their innovations and to give the MIT community the opportunity to learn from their practices. The awards are co-sponsored by Open Learning and the Office of the Vice Chancellor.

DOE Early Career Research Award: Each year, the DoE selects researchers for significant funding "nation's scientific workforce by providing support to exceptional researchers during crucial early career years, when many scientists do their most formative work." Manthiram is working to synthesize chemicals and materials in a sustainable manner that eliminates the carbon footprint. With the support of the DoE Early Career Award, the Manthiram lab is specifically looking at how water can be used as a source of oxygen atoms to convert alkenes, which are two carbon atoms attached by a double bond, into an epoxide, a triangular configuration of two carbon atoms and an oxygen atom.

Karthish Manthiram and Zachary Smith named to AIChE's 2020 35 under 35 list

The AIChE 35 Under 35 Award honors engineers under the age of 35 who have made significant contributions to the Institute and to the chemical engineering profession. AIChE and the Young Professionals Committee (YPC), with support from the AIChE Foundation, are recognizing this year's 35 outstanding young AIChE members. The AIChE 35 Under 35 Award was founded to recognize young chemical engineers who have achieved greatness in their fields. The winners are a group of driven, engaged, and socially active professionals, representing the breadth and diversity that chemical engineering exemplifies.

Kristala Prather named fellow of AIMBE

The American Institute for Medical and Biological Engineering (AIMBE) is a non-profit organization representing the most accomplished individuals in the fields of medical and biological engineering. It brings together academia, industry, government, and scientific societies to form a highly influential community advancing medical and biological engineering. AIMBE's mission is to provide leadership and advocacy in medical and biological engineering for the benefit of society.

The health and value of AIMBE as an advocate for public policy issues related to improving lives through medical and biological engineering is ensured by a College of Fellows comprised of experts in areas such as clinical practice, industrial practice, and education. Fellows and constituents of AIMBE cultivate ideas and address current issues by attending national events intended to advance the mission of AIMBE.

Greg Stephanopoulos receives honorary doctorate from TU Dortmund, Germany

Stephanopoulos was recognized for this outstanding achievements in the development of biochemical engineering research and lifetime contributions to the field. The citation states, "Stephanopoulos has expanded and transformed the field of biochemical engineering in countless ways, and has helped advance metabolic engineering in particular from a nascent concept to a thriving discipline. He continues to discover, educate, and inspire at the highest levels."

Will Tisdale named 2020 MacVicar Faculty Fellow

For nearly three decades, the MacVicar Faculty Fellows Program has been recognizing exemplary undergraduate teaching and advising around the Institute. Nominations are made by departments and include letters of support from colleagues, students, and alumni.

Tisdale's colleague Kristala Prather calls him a "curriculum fixer." During an internal review of Course 10 subjects, the department discovered that 10.213 (Chemical and Biological Engineering) was the least popular subject in the major and needed to be revised. After carefully evaluating the coursework, and despite having never taught 10.213 himself, Tisdale envisioned a novel way of teaching it. With his suggestions, the class went from being "despised" to loved, with subject evaluations improving by 70 percent from one spring to the next. X

A controllable membrane to pull carbon dioxide out of exhaust streams

Electrically switchable system could continuously separate gases without the need for moving parts or wasted space.

David L. Chandler, MIT News Office

A new system developed by the Hatton Lab could provide a way of continuously removing carbon dioxide from a stream of waste gases, or even from the air. The key component is an electrochemically assisted membrane whose permeability to gas can be switched on and off at will, using no moving parts and relatively little energy.

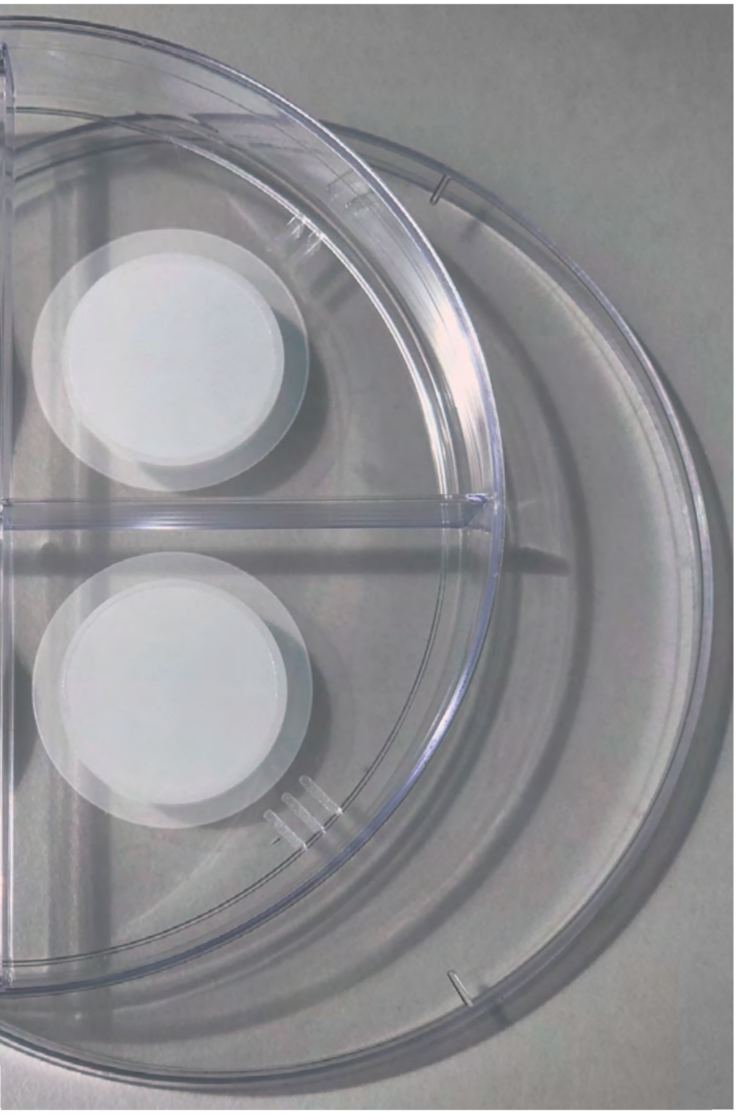
The membranes themselves, made of anodized aluminum oxide, have a honeycomb-like structure made up of hexagonal openings that allow gas molecules to flow in and out when in the open state. However, gas passage can be blocked when a thin layer of metal is electrically deposited to cover the pores of the membrane. The work is described today in the journal *Science Advances*, in a paper by Professor T. Alan Hatton, postdoc Yayuan Liu, and four others.

This new “gas gating” mechanism could be applied to the continuous removal of carbon dioxide from a range of industrial exhaust streams and from ambient air, the team says. They have built a proof-of-concept device to show this process in action.

The device uses a redox-active carbon-absorbing material, sandwiched between two switchable gas gating membranes. The sorbent and the gating membranes are in close contact with each other and are immersed in an organic electrolyte to provide a medium for zinc ions to shuttle back and forth. These two gating membranes can be opened or closed electrically by switching the polarity of a voltage between them, causing ions of zinc to shuttle from one side to the other. The ions simultaneously block one side, by forming a metallic film over it, while opening the other, by dissolving its film away.

When the sorbent layer is open to the side where the waste gases are flowing by, the material readily soaks up carbon dioxide until it reaches its capacity. The voltage can then be switched to block off the feed side and open up the other side, where a concentrated stream of nearly pure carbon dioxide is released.

By building a system with alternating sections of membrane that operate in opposite phases, the system would allow for continuous operation in a setting such as an industrial



On the right is a porous anodized aluminum oxide membrane. The left side shows the same membrane after coating it with a thin layer of gold, making the membrane conductive for electrochemical gas gating. Credit: Felice Frankel

scrubber. At any one time, half of the sections would be absorbing the gas while the other half would be releasing it.

"That means that you have a feed stream coming into the system at one end and the product stream leaving from the other in an ostensibly continuous operation," Hatton says. "This approach avoids many process issues" that would be involved in a traditional multicolumn system, in which adsorption beds alternately need to be shut down, purged, and then regenerated, before being exposed again to the feed gas to begin the next adsorption cycle. In the new system, the purging steps are not required, and the steps all occur cleanly within the unit itself.

The researchers' key innovation was using electroplating as a way to open and close the pores in a material. Along the way the team had tried a variety of other approaches to reversibly close pores in a membrane material, such as using tiny magnetic spheres that could be positioned to block funnel-shaped openings, but these other methods didn't prove to be efficient enough. Metal thin films can be particularly effective as gas barriers, and the ultrathin layer used in the new system requires a minimal amount of the zinc material, which is abundant and inexpensive.

"It makes a very uniform coating layer with a minimum amount of materials," Liu says. One significant advantage of the electroplating method is that once the condition is changed, whether in the open or closed position, it requires no energy input to maintain that state. Energy is only required to switch back again.

Potentially, such a system could make an important contribution toward limiting emissions of greenhouse gases into the atmosphere, and even direct-air capture of carbon dioxide that has already been emitted.

The research team included graduate student Chun-Man Chow, postdoc Katherine Phillips, and recent graduates Miao Wang PhD '20 and Sahag Voskian PhD '19. This work was supported by ExxonMobil through the MIT Energy Initiative. X

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

Research Highlights

“Living drug factories” might treat diabetes and other diseases

One promising way to treat diabetes is with transplanted islet cells that produce insulin when blood sugar levels get too high. However, patients who receive such transplants must take drugs to prevent their immune systems from rejecting the transplanted cells, so the treatment is not often used.

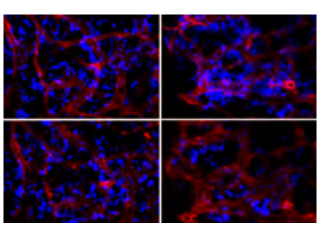
To help make this type of therapy more feasible, the Anderson Lab has now devised a way to encapsulate therapeutic cells in a flexible protective device that prevents immune rejection while still allowing oxygen and other critical nutrients to reach the cells. Such cells could pump out insulin or other proteins whenever they are needed.

MIT researchers have devised a way to encapsulate therapeutic cells, such as pancreatic islet cells, to treat diabetes, in a flexible protective device.

Nanoparticles can turn off genes in bone marrow cells

Using specialized nanoparticles, The Anderson Lab and colleagues have developed a way to turn off specific genes in cells of the bone marrow, which play an important role in producing blood cells. These particles could be tailored to help treat heart disease or to boost the yield of stem cells in patients who need stem cell transplants, the researchers say.

This type of genetic therapy, known as RNA interference, is usually difficult to target to organs other than the liver, where nanoparticles would tend to accumulate. The MIT researchers were able to modify their particles in such a way that they would accumulate in the cells found in the bone marrow.



MIT researchers have shown they can deliver RNAi nanoparticles to the bone marrow, influencing their function. At top right, the bone marrow is not yet treated with particles that turn off a gene called SDF1. At bottom right, the number of neutrophils (blue) decreases, indicating that they have been released from bone marrow after treatment. At left, treatment with a control nanoparticle does not affect the number of neutrophils before and after treatment.

Chung Lab develops SCOUT to help researchers study organoids

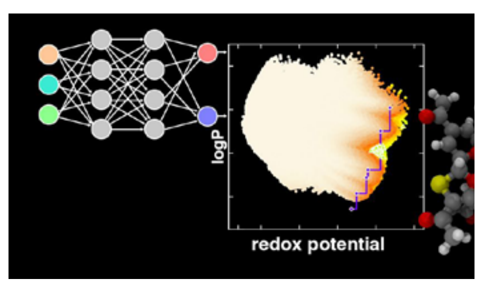
The ability to culture cerebral organoids or “minibrains” using stem cells derived from people has given scientists experimentally manipulable models of human neurological development and disease, but not without confounding challenges. No two organoids are alike and none of them resemble actual brains. This “snowflake” problem has held back the science by making scientifically meaningful quantitative comparisons difficult to achieve. To help researchers overcome those limitations, MIT neuroscientists and engineers have developed a new pipeline for clearing, labeling, 3D imaging and rigorously analyzing organoids.

Called “SCOUT” for “Single-Cell and Cytoarchitecture analysis of Organoids using Unbiased Techniques,” the process can extract comparable features among whole organoids despite their uniqueness — a capability the researchers demonstrate via three case studies in their new paper in *Scientific Reports*.

Neural networks facilitate optimization in the search for new materials

When searching through theoretical lists of possible new materials for particular applications, such as batteries or other energy-related devices, there are often millions of potential materials that could be considered, and multiple criteria that need to be met and optimized at once. Now, the Kulik Lab has found a way to dramatically streamline the discovery process, using a machine learning system.

As a demonstration, the team arrived at a set of the eight most promising materials, out of nearly 3 million candidates, for an energy storage system called a flow battery. This culling process would have taken 50 years by conventional analytical methods, they say, but they accomplished it in five weeks.



An iterative, multi-step process for training a neural network, as depicted at top left, leads to an assessment of the tradeoffs between two competing qualities, as depicted in graph at center. The blue line represents a so-called Pareto front, defining the cases beyond which the materials selection cannot be further improved. This makes it possible to identify specific categories of promising new materials, such as the one depicted by the molecular diagram at right.

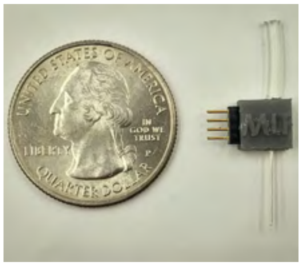


Photo shows the device the team developed. The tube at top is connected to a supply of the precursor material, sodium nitrite, which then passes through a channel in the fiber at the bottom and into the body, which also contains the electrodes to stimulate the release of nitric oxide. The electrodes are connected through the four-pin connector on the left.

Producing a gaseous messenger molecule inside the body, on demand

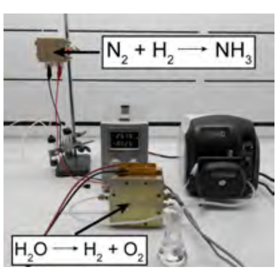
Nitric oxide is an important signaling molecule in the body, with a role in building nervous system connections that contribute to learning and memory. It also functions as a messenger in the cardiovascular and immune systems.

But it has been difficult for researchers to study exactly what its role is in these systems and how it functions. Because it is a gas, there has been no practical way to direct it to specific individual cells in order to observe its effects. Now, the Manthiram Lab, with a team of scientists and engineers at MIT and elsewhere, has found a way of generating the gas at precisely targeted locations inside the body, potentially opening new lines of research on this essential molecule's effects.

Manthiram Lab's technique could enable cheaper fertilizer production

Most of the world's fertilizer is produced in large manufacturing plants, which require huge amounts of energy to generate the high temperatures and pressures needed to combine nitrogen and hydrogen into ammonia.

MIT chemical engineers are working to develop a smaller-scale alternative, which they envision could be used to locally produce fertilizer for farmers in remote, rural areas, such as sub-Saharan Africa. Fertilizer is often hard to obtain in such areas because of the cost of transporting it from large manufacturing facilities. In a step toward that kind of small-scale production, the research team has devised a way to combine hydrogen and nitrogen using electric current to generate a lithium catalyst, where the reaction takes place.



A photograph depicting a model of an electrochemical Haber-Bosch reactor coupled to a water electrolyzer, with the reactors highlighted.

Strano Lab's nanosensor can alert a smartphone when plants are stressed

The Strano Lab has developed a way to closely track how plants respond to stresses such as injury, infection, and light damage, using sensors made of carbon nanotubes. These sensors can be embedded in plant leaves, where they report on hydrogen peroxide signaling waves.

Plants use hydrogen peroxide to communicate within their leaves, sending out a distress signal that stimulates leaf cells to produce compounds that will help them repair damage or fend off predators such as insects. The new sensors can use these hydrogen peroxide signals to distinguish between different types of stress, as well as between different species of plants.

MIT chemical engineers have designed a sensor that can be embedded into plant leaves and measure hydrogen peroxide levels, which indicate that damage has occurred. The signal can be sent to a nearby smartphone.

Mathematical model could lead to better treatment for diabetes

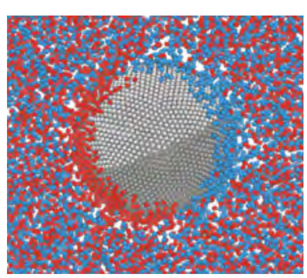
One promising new strategy to treat diabetes is to give patients insulin that circulates in their bloodstream, staying dormant until activated by rising blood sugar levels. However, no glucose-responsive insulins (GRIs) have been approved for human use, and the only candidate that entered the clinical trial stage was discontinued after it failed to show effectiveness in humans.

The Strano Lab has now developed a mathematical model that can predict the behavior of different kinds of GRIs in both humans and in rodents. They believe this model could be used to design GRIs that are more likely to be effective in humans, and to avoid drug designs less likely to succeed in costly clinical trials.

Study by the Swan Lab finds electrical fields can throw a curveball

The Swan Lab has discovered a phenomenon that could be harnessed to control the movement of tiny particles floating in suspension. This approach, which requires simply applying an external electric field, may ultimately lead to new ways of performing certain industrial or medical processes that require separation of tiny suspended materials.

The findings are based on an electrokinetic version of the phenomenon that gives curveballs their curve, known as the Magnus effect. Zachary Sherman PhD '19, who is now a postdoc at the University of Texas at Austin, and Professor Swan describe the new phenomenon in a paper published in the journal *Physical Review Letters*. **X**



MIT researchers have discovered a phenomenon that could be harnessed to control the movement of tiny particles floating in suspension. This approach, which requires simply applying an external electrical field, may ultimately lead to new ways of performing certain industrial or medical processes that require separation of tiny suspended materials.

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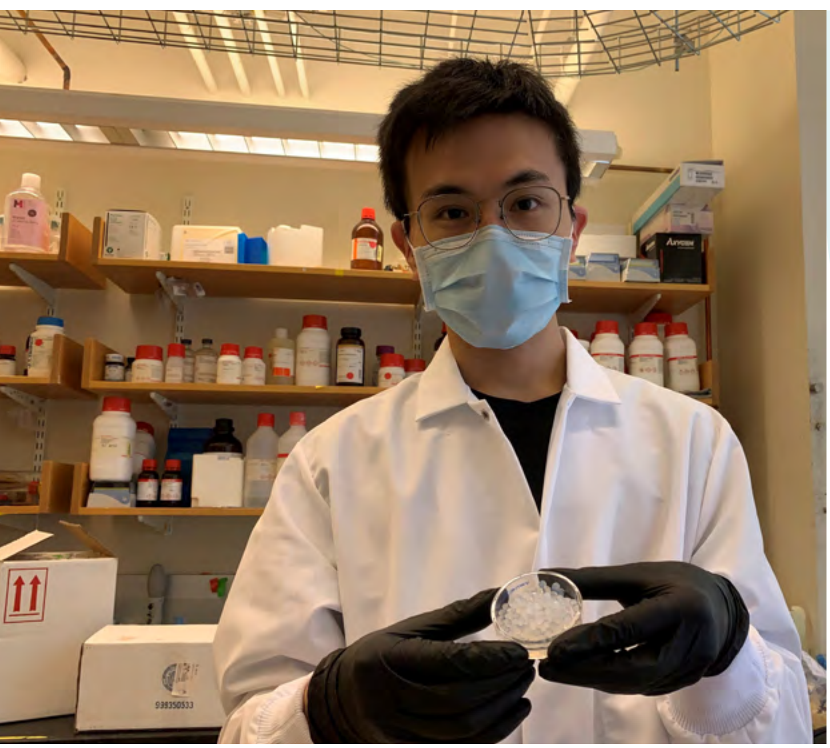
A new platform for controlled delivery of key nanoscale drugs and more

The novel approach, developed by MIT chemical engineers, could help create more efficient consumer products, including drugs, cosmetics, and food.



Liang-Hsun Chen holds the nanoemulsion-loaded capsules he created.
Credits: courtesy of Liang-Hsun Chen

In work that could have a major impact on several industries — from pharmaceuticals to cosmetics and even food — MIT engineers have developed a novel platform for the controlled delivery of certain important drugs, nutrients, and other substances to human cells.

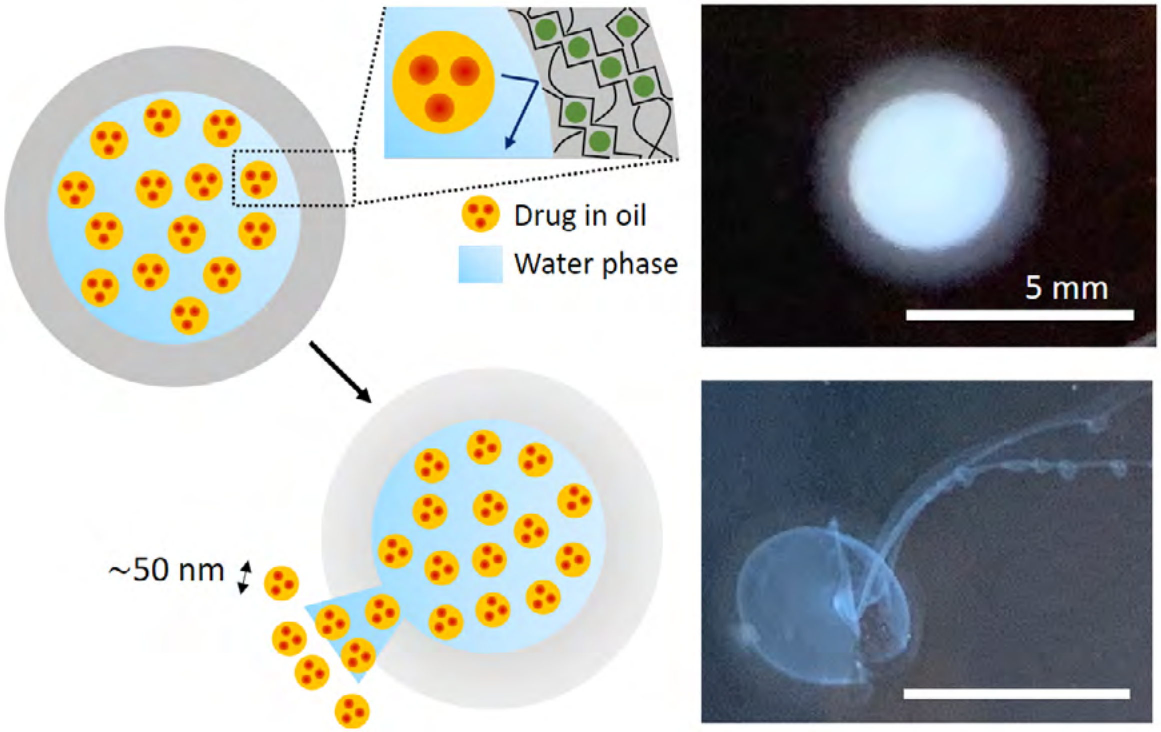
The researchers believe that their simple approach, which creates small capsules containing thousands of nanosized droplets loaded with a drug or other active ingredient, will be easy to transition from the lab to industry.

The active ingredients in many consumer products intended for use in or on the human body do not easily dissolve in water. As a result, they are hard for the body to absorb, and it is difficult to control their delivery to cells.

In the pharmaceutical industry alone, "40 percent of currently marketed drugs and 90 percent of drugs in development are hydrophobic wherein [their] low water solubility greatly limits their bioavailability and absorption efficiency," the MIT team writes in a paper on the work in the August 28 issue of the journal Advanced Science.

Nanoemulsions to the Rescue

Those drugs and other hydrophobic active ingredients do, however, dissolve in oil. Hence the growing interest in nanoemulsions, the nanoscale equivalent of an oil-and-vinegar salad dressing that consists of miniscule droplets of oil dispersed in water. Dissolved in each oil droplet is the active ingredient of interest.



These schematics and photographs illustrate a) a small capsule containing thousands of nano-sized droplets loaded with a drug or other active ingredient; and b) how the droplets burst from the capsule after a set amount of time. Images: Liang-Hsun Chen

Among other advantages, the ingredient-loaded droplets can easily pass through cell walls. Each droplet is so small that between 1,000 to 5,000 could fit across the width of a human hair. (Their macroscale counterparts are too big to get through.) Once the droplets are inside the cell, their payload can exert an effect. The droplets are also exceptionally stable, resulting in a long shelf life, and can carry a large amount of active ingredient for their size.

But there's a problem: How do you encapsulate a nanoemulsion into a dosage form like a pill? The technologies for doing so are still nascent.

In one of the most promising approaches, the nanoemulsion is encapsulated in a 3D network of a polymer gel to form small beads. Currently, however, when ingested those beads release their payload — the ingredient-loaded oil droplets — all at once. There is no control over the process.

The MIT team solved this by adding a shell, or capsule, around large individual droplets of nanoemulsion, each containing thousands of nano oil droplets. That shell not only protects the nano droplets inside from harmful physiological conditions in the body, but also could be used to mask the often unpalatable taste of the active ingredients they contain.

The result is a "pill" about 5 millimeters in diameter with a biodegradable shell that in turn can be "tuned" to release its contents at specific times. This is done by changing the thickness of the shell. To date they have successfully tested the system with both ibuprofen and Vitamin E.

"Our new delivery platform can be applied to a broad range of nanoemulsions, which themselves contain active ingredients ranging from drugs to nutraceuticals and sunscreens. Having this new control over how you deliver them opens up many new avenues in terms of future applications," says Patrick Doyle, the Robert T. Haslam Professor of Chemical Engineering and senior author of the paper.

His colleagues on the work are Liang-Hsun Chen, a graduate student in chemical engineering and first author of the paper, and Li-Chiun Cheng SM '18, PhD '20, who received his PhD in chemical engineering earlier this year and is now at LiquiGlide.

Doyle notes that from a pedagogical point of view, the work "combined all of the core elements of chemical engineering, from fluid dynamics to reaction engineering and mass transfer. And to me it's pretty cool to have them all in one project."

This work was supported by the Singapore National Research Foundation, the U.S. National Science Foundation, and the Think Global Education Trust (Taiwan). X

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

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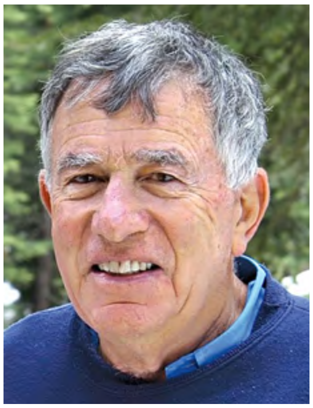
Alumni Highlights



Peter Spitz '48 SM '49 was profiled by *MIT Technology Review* (TR), and discussed his new book, *Primed for Success: The Story of Scientific Design Company* (Springer, 2019). The TR article states that "[t]he book reveals the critical role that chemical engineers — and MIT engineers in particular — played in creating a vast complex of synthetic rubber plants during World War II, using brand-new technologies. In the process, they shifted the chemical industry's focus from coal, alcohol, and wood to petroleum. In fact, he adds, he could have subtitled the book 'How MIT Chemical Engineers Created the Petrochemical Industry.'"

Aditya Kunjapur PhD '15 has received AIChE's 2020 35 Under 35 Award. An assistant professor at the University of Delaware, Kunjapur focuses on microbial chemistry using protein and metabolic engineering techniques — he teaches cells to make and integrate amino acids that can stimulate the immune system or respond to light or oxygen. Kunjapur also seeks to improve engineering education and access to it using online platforms such as YouTube. He enjoys traveling and singing karaoke with his wife.

Zachary Ulissi PhD '15 has received AIChE's 2020 35 Under 35 Award. An assistant professor at Carnegie Mellon, Ulissi works on the development and application of high-throughput simulation methods, active learning methods, and machine learning models for surface science and catalysis. He is excited to be part of a wave of young faculty applying data science and machine learning tools to traditional engineering problems. Ulissi is also a competitive cyclist and he met his wife on a collegiate cycling team.

Kedi Hu '20 has been named a 2020 Fulbright Scholar. Sponsored by the U.S. Department of State, the Fulbright U.S. Student Program offers opportunities for American student scholars in over 160 countries. Hu graduated with double majors in chemical engineering and architecture. Passionate about sustainable development, she has worked on a number of academic and professional projects addressing environmental problems, including water scarcity, pollution capture, and grid-scale energy storage. For her Fulbright research grant at Tsinghua University in China, Hu plans to develop biodegradable electrospun membranes for air filtration applications. After Fulbright, Hu will matriculate at Columbia University to pursue a doctorate degree in chemical engineering, continuing research on grid-scale energy storage to enable a 100 percent renewable world.

Michal Gala '20 was named a 2020 Knight-Hennessy Scholar. The prestigious fellowship attracts thousands of applicants from around the world and provides full funding for graduate studies in any field at Stanford University. Knight-Hennessy scholars also receive leadership development training, mentorship, and experiential learning opportunities. Gala, from Gliwice, Poland, aspires to engineer novel clean processes and technologies that will create the chemical industry of the future and help solve the problem of climate change. At MIT, he tackled similar problems experimentally and computationally. Gala has interned at Shell in India and Schlumberger developing artificial intelligence tools for accelerated materials discovery and property prediction. Throughout his time at MIT, he worked on electrochemical ammonia synthesis, elucidating key parts of this promising technology, for which he was recognized as one of 25 under 25 in Science by Polish Forbes.

In Memoriam: Henry T. Brown SM ’56

On Thursday, February 13, 2020, Dr. Henry Brown, SM ’56, passed away. Dr. Brown was well known as an advocate for minorities in engineering, especially chemical engineering. An AIChE Fellow and a recipient of many honors, he was a very active MIT alumnus and advocate. Many in the Department know him from his frequent visits and special events throughout the year. He is dearly missed.

Dr. Brown is one of the original advocates for minority engineers in AIChE, beginning in 1968. He co-created AIChE’s first outreach initiatives for underrepresented engineers, and held the position of AIChE’s Minority Affairs Coordinator from 1983 through 2001. Dr. Brown was one of the founders of the New Jersey State Urban Science Education Coalition, and is a Diamond Life Member of the National Association for the Advancement of Colored People (NAACP).

Dr. Brown earned his BS in chemical engineering from the University of Cincinnati in 1955, where he was the first African American to do so. Dr. Brown has received an array of awards for his work, which include: the Martin K. Simberloff Memorial Award in 1960, presented by the Urban League of Union County, New Jersey; the Big Brother Award for Outstanding Service to Youth in 1965, the Distinguished Alumni Award , presented by the University of Cincinnati in 1983; the F.J. and Dorothy Van Antwerpen Award for Service to the Institute, presented by the AIChE in 1996; an honorary doctorate of science degree from the University of Cincinnati in 2001; and the 2004 Grimes and 2015 Pioneer of Diversity Awards, both presented by the AIChE’s Minority Affairs Committee. In 2018, the AIChE renamed their Minority Affairs Committee Endowment Fund the Henry T. and Melinda C. Brown Minority Affairs Endowment Fund.

In 2018, AIChE established in the Henry T. Brown Endowment for the Education of Underrepresented Minority Chemical Engineers, a key program to support the advancement of diversity and inclusion in AIChE and the chemical engineering profession. Gerry Lessells, a longtime friend of Dr. Brown who collaborated with him on AIChE’s earliest minority outreach activities, made the initial gift. He says of Dr. Brown, “Henry has given unstintingly of himself in expanding AIChE’s diversity and inclusion over a period of 50 years… This is especially true of his getting the Institute to establish its Minority Affairs Committee and his continually nurturing over a 27-year period the activities and membership of this most important National Committee.” X

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Lighting the way to better battery technology

Practice School alumnus Supratim Das wants the world to know how to make longer-lasting batteries that charge mobile phones and electric cars.

Supratim Das's quest for the perfect battery began in the dark. Growing up in Kolkata, India, Das saw that a ready supply of electric power was a luxury his family didn't have. "I wanted to do something about it," Das says. Now a fourth-year PhD candidate in MIT chemical engineering who's months away from defending his thesis, he's been investigating what causes the batteries that power the world's mobile phones and electric cars to deteriorate over time.

Lithium-ion batteries, so-named for the movement of lithium ions that make them work, power most rechargeable devices today. The element lithium has properties that allow lithium-ion batteries to be both portable and powerful; the 2019 Nobel Prize in Chemistry was awarded to scientists who helped develop them in the late 1970s. But despite their widespread use, lithium-ion batteries, essentially a black box during operation, harbor mysteries that prevent scientists from unlocking their full potential. Das is determined to demystify them, by first understanding their flaws.

In his doctoral research, Das and collaborators have been able to understand the microscopic changes that degrade a battery's electrodes over its lifetime, and develop multiscale physics-based models to predict them in a robust manner at the macro-scale. Such multiscale models can aid battery manufacturers to substantially reduce battery health diagnostics costs before it is incorporated into a device, and make batteries safer for consumers. In his latest project, he's using that knowledge to investigate the best way of charging a lithium-ion battery without damaging it. Das hopes his contributions help scientists achieve further breakthroughs in battery science and make batteries safer, especially when the latest technology is often closely guarded by private companies. "What our group is trying to do is improve the quality of open access academic literature," Das says. "So that when other people are trying to start their research in batteries, they don't have to start at the theory from five to 10 years ago."

In his second year of graduate work, Das spent a semester at the Practice School in stations at Shell in Houston, Texas and Emirates Global Aluminum in Dubai. There, he learned lessons that would prove invaluable in his graduate work. "It taught me problem formulation," Das says. "Identifying what is relevant for stakeholders; what to work on so as to best use the team's skill sets; how to distribute your time."

After Das's Practice School experience, he discovered that

as a scientist he could share valuable knowledge about battery research and the future of the technology with energy economists. He also realized that policymakers considered their own criteria when investing in technology for the future. Das believed that such a perspective would help him inform policy decisions as a scientist, so he decided that after completing his PhD, he would pursue an MBA focusing on energy economics and policy at MIT's Sloan School of Management. "It will allow me to contribute more to society if I'm able to act as a bridge between someone who understands the hardcore, microscopic physics of a battery, and someone who understands the economic and policy implications of introducing that battery into a vehicle or a grid," Das says.

Das believes that the program, which begins next fall, will allow him to work with other energy experts who bring their own knowledge and skills to the table. He understands the power of collaboration well: at college, Das was elected president of a dorm of 450-plus residents and worked with students and administration to introduce new facilities and events on campus. After arriving in Cambridge, Massachusetts, Das helped other students manage Ashdown House, represented chemical engineering students on the Graduate Student Advisory Board, and served in the leadership team for the MIT Energy Club, spearheading the organization of MIT EnergyHack 2019. He also launched a community service initiative within the Department of Chemical Engineering; once a week, students mentor school children and volunteer at nonprofits in Cambridge. He was able to attract funding for his initiative and was awarded by the department for successfully mobilizing 80-plus students in the community within the span of a year. "I'm constantly surprised at what we can achieve when we work with other people," Das says.

After all, other people have helped Das make it this far. "I owe a lot of success to a number of sacrifices my mom made for me, including giving up her own career," he says. At MIT, he feels fortunate to have met mentors like his advisor, Martin Bazant, and Practice School directors Robert Fisher and Brian Stutts, and the many colleagues who have offered answers to his questions. "Here, I've discovered what it means to synergize with really smart people who are really passionate — and really nice at the same time," Das says. "Grateful is the one word I'd use." X

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Keep in touch — we hope to see you soon! Save the dates:

Friday, May 7, 2021
Warren K. Lewis Lectureship

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

Tuesday, May 25, 2021
Hoyt C. Hottel Lectureship

Frances Arnold, Linus Pauling Professor of Chemical Engineering, Bioengineering, and Biochemistry, California Institute of Technology

2018 Nobel Laureate in Chemistry

For 2020 Commencement, the Department created alumni t-shirts. These are now available to all alumni for purchase. If you are interested in getting one, contact melmils@mit.edu. The online store closes March 1, 2021.

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