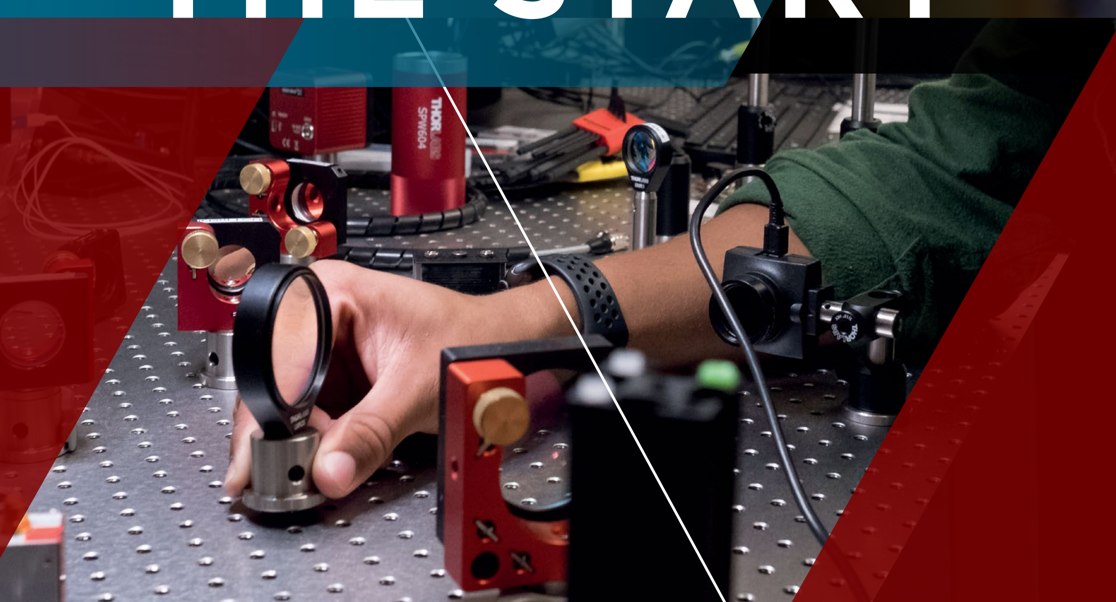
THE UNIVERSITY OF CHICAGO
PRITZKER SCHOOL OF MOLECULAR ENGINEERING

10 YRS

GROUND BREAKING RIGHT FROM THE START



Message from the Dean

In May 2019, a gift from the Pritzker Foundation supported the transformation of the Institute for Molecular Engineering (IME) into the Pritzker School of Molecular Engineering (PME), the first school in the nation dedicated to engineering systems from the atomic and molecular level up. Over ten years of intensive growth, Pritzker Molecular Engineering has largely achieved, and in several respects surpassed, the original plan for the establishment of the IME.

Since 2011, PME has grown from an idea and a proposal into a thriving enterprise with four strong, distinctive themes; a faculty of 32 primary appointments and 12 secondary appointments; undergraduate majors numbering more than 70; more than 200 PhD students; and about 90 postdoctoral researchers and 15 research staff; as well as major core facilities in nanofabrication, bioengineering, organic materials synthesis, and characterization.

PME started with the mission to profoundly affect the future of engineering and applied science research and education, and, ultimately, to benefit humanity and improve quality of life. Our focus on a few singular, transformative topics in engineering science has enabled us to compete with the very best traditional engineering programs in these areas. We believe that this style of program building will continue to yield good results.

Our research themes—Immunoengineering; Materials Systems for Sustainability and Health; and Quantum Engineering—provide the vehicle for us to accomplish our mission.

In Immunoengineering, PME researchers have developed new therapies for autoimmune diseases such as multiple sclerosis, as well as new cancer immunotherapy methods. An innovation known as Nanotraps was shown to sequester and inactivate the coronavirus that causes COVID.

Under Materials Systems for Sustainability and Health, we have devised new methods for extracting rare elements from sea water, created devices that conform to and read physiological signals from the human body, and developed nanoparticles that show promise in treating cardiovascular disease.

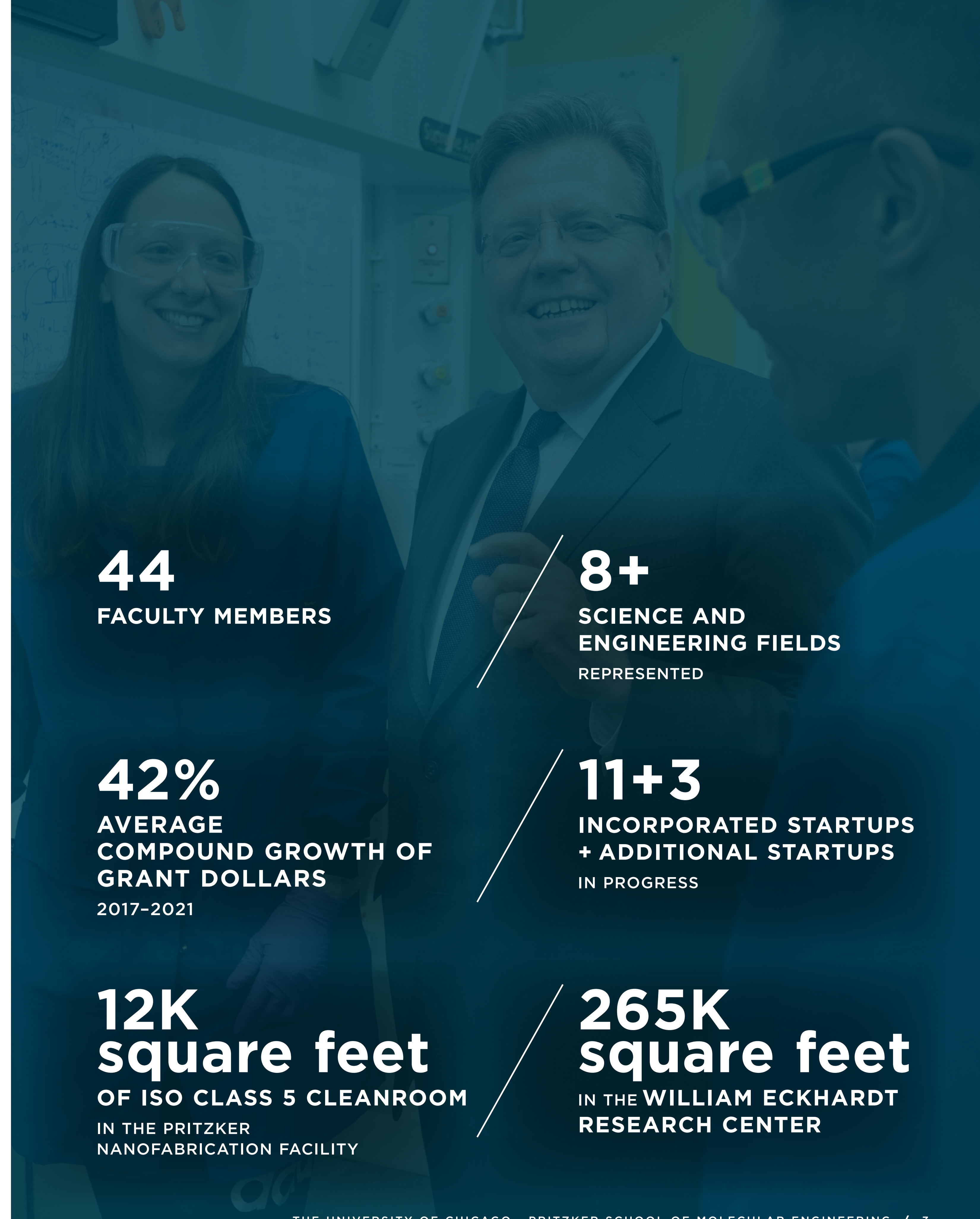
We have seen great advancements and innovations in quantum engineering. In a breakthrough for quantum computing, PME researchers have sent entangled qubit states through a communication cable linking one quantum network node to a second node. The growth of industrial support in the Chicago Quantum Exchange (CQE) and the establishment of the first quantum technology accelerator, Duality, indicate the power and success of our quantum engineering efforts.

We aim for the same level of innovation in our educational programs as we do in our research. Distinctive graduate education flows inextricably and nearly automatically from the novel structure of PME, which is agnostic to traditional engineering disciplines. In the undergraduate programs in molecular engineering, we aim to prepare students for leadership roles in a technological society. Innovation in the BS in Molecular Engineering is driven and shaped not only by the ambition to design programs that are forward looking and not rooted in the historical curriculum of established engineering disciplines, but also by the distinct and deep liberal arts culture at the University of Chicago.

Entering this next phase of PME development, it is now clear that molecular engineering provides a powerful over-arching marquee for developing technologies from the atomic and molecular level up. Under the molecular engineering banner, PME will continue to define multiple new fields spanning the broad practice and profession of engineering in a unique and influential way. I look forward to leading PME through this next era of growth, and thank all those who have helped make our program a success.

Matthew Tirrell

Matthew Tirrell
Dean, Pritzker School of Molecular Engineering



44
FACULTY MEMBERS

8+
SCIENCE AND ENGINEERING FIELDS
REPRESENTED

42%
AVERAGE COMPOUND GROWTH OF GRANT DOLLARS
2017–2021

11+3
INCORPORATED STARTUPS + ADDITIONAL STARTUPS
IN PROGRESS

12K square feet
OF ISO CLASS 5 CLEANROOM
IN THE PRITZKER NANOFABRICATION FACILITY

265K square feet
IN THE **WILLIAM ECKHARDT RESEARCH CENTER**

The seven-story, 265,000 square-foot William Eckhardt Research Center houses the majority of PME lab and office space.

TURNING AN IDEA INTO A THRIVING INSTITUTION

How the University of Chicago created the country's first school for molecular engineering

Long before there was a Pritzker School of Molecular Engineering (PME) at the University of Chicago, there were three people with an idea.

Robert J. Zimmer, then-president of the University of Chicago, Thomas J. Pritzker, MBA'76, JD'76 University trustee, and Thomas F. Rosenbaum, then-provost, wanted to bring a novel field of engineering to the University, one poised to revolutionize technology as dramatically as the emergence of computer science. They wanted to create an institute dedicated to molecular engineering and, in doing so, position Chicago as the epicenter of that new technological era.

Pritzker and Zimmer first realized they harbored the same dream while chatting at a cocktail party in 2006, not long after Zimmer had become UChicago's 13th president. Soon after, Pritzker called Zimmer and said he'd like to finance an Institute for Molecular Engineering, offering a $10 million founding gift—despite the fact that the "institute" did not yet have a physical location, faculty, or plan. It was the start of a visionary partnership.

/ Unequivocally yes

Buoyed by Pritzker's offer, Zimmer then requested that the University create an exploratory committee and charged it with assessing the feasibility of such a program. That committee, chaired by Steven J. Sibener, the Carl William Eisendrath Distinguished Service Professor in Chemistry, consulted broadly with University faculty and held numerous town hall meetings over the following year.

Among their considerations was the University's historic focus on basic science and its long-standing relationship with Argonne National Laboratory, both of which would stand to grow and evolve with the establishment of a new school. At the end of its review, the committee returned with its answer: an unequivocal, enthusiastic yes.

That same conclusion was echoed by an external committee, chaired by Robert Langer of MIT, which stated that, "a great university has an obligation to work on the biggest problems of the times, and some of the great problems of this time—in energy, health, global stewardship, and others—will require engineering for their solution. The University is, we agree, entirely correct in considering how to engage in engineering."

The findings of both committees were distilled in a series of reports, creating the blueprint for molecular engineering at the University of Chicago.

/ A perfect fit

To create the program envisioned by Pritzker and Zimmer, the University would need someone to lead it, a dean who shared its vision and who was comfortable reimagining the boundaries of higher education. They found that leader in Matthew Tirrell.

"I can almost picture myself, sitting in my office at Berkeley, opening up this email, and being struck by this plan," said Tirrell, recalling how quickly he decided to come to UChicago. "I knew it was what I wanted to do for the rest of my active professional career."

To Tirrell, the chance to build an engineering school from the ground up was a rare opportunity. And because this was the University of Chicago's entrance into applied science and engineering, there were virtually no institutional barriers—Tirrell could build the program with great freedom.

In addition, UChicago's partnership with Argonne National Laboratory would give faculty and students access to state-of-the-art facilities and an allied technical workforce of the caliber that few engineering programs in the country could afford. And the Pritzker Foundation would soon give more funding, financing a fabrication lab—the Pritzker Nanofabrication Facility—which is fundamental to work in molecular engineering.

> **"We wanted to create an environment where people weren't so focused on what the disciplines are, but what the disciplines can do."**
>
> **Matthew Tirrell**
> Dean, Pritzker School of Molecular Engineering

/ People power

Hired in 2011, Tirrell got to work right away. He sought out scientists who shared the program's core philosophy,

The Pritzker Nanofabrication Facility is equipped with a full suite of lithographic, deposition, and etching tools.

listened to what they wanted to do, and showed them how they could do it within the new program.

"I wanted versatile people who could think about applications outside of one field. They might have expertise rooted in healthcare, but could they apply it to energy or environment or computing? How can biology transform information?" Tirrell said. "We wanted to find people interested in convergent research. For instance, we envisioned researchers skilled in biology and bioengineering working alongside people skilled in applied physics and electrical engineering to find solutions to some of today's grand challenges."

And that's exactly who Tirrell recruited. In 2012 and 2013, Tirrell hired the program's first four senior faculty: David Awschalom, Juan de Pablo, Nancy Kawalek, and Paul Nealey. In hiring them, the program's organizing philosophy began to take shape: a school focused on the strength of its people rather than the predetermined boundaries of one particular field.

"We wanted to create an environment where people weren't so focused on what the disciplines are, but what the disciplines can do," explained Tirrell.

The institute began forming its major areas of focus. However, rather than set up traditional departments, it created interdisciplinary themes focused on issues that impact humanity and quality of life. These centered on quantum engineering, immunoengineering, and materials systems for sustainability and health.

/ More faculty, new digs

With its core faculty and research areas in place, the program began a flurry of development. It introduced a PhD program and helped bring to life the University's new molecular engineering major. It continued to grow and deepen its relationship with Argonne. Today, faculty from PME hold positions across the national lab's directorate, including several leadership roles. There's also now a formalized mechanism to foster the flow of students from the University to Argonne, giving the national lab access to vibrant, creative human resources and UChicago students the opportunity to gain experience in an environment uniquely different from the academic world.

PME also drew in more senior faculty including Andrew Cleland, Guilia Galli, Jeffrey Hubbell, and Melody Swartz—expanding research and sparking new projects. In fact, with so much development, the program was pushing its physical boundaries until, in October 2015, the William Eckhardt Research Center (ERC) opened and the institute moved into its new home.

Over the next few years, faculty increased to 25, then to 33. The first class of undergraduate molecular engineers graduated. The University of Chicago, the University of Illinois Urbana-Champaign, Argonne, and Fermilab launched the Chicago Quantum Exchange (CQE). Outreach programs bloomed, cementing PME's commitment to addressing inequality and forging new relationships with local communities.

/ From Institute to School

Then, in 2019, the Pritzker Foundation committed $100 million to support the University's molecular engineering program. In recognition of the program's success, impact, and the ongoing and planned major expansion of its research and education programs, the Pritzker Foundation's increased support elevated what had been the Institute for Molecular Engineering to the Pritzker School of Molecular Engineering (PME), making it the first school in the nation dedicated to the fast-growing field of molecular engineering, and the first new school at the University in three decades.

"The Pritzker Foundation has been committed to the idea of molecular engineering since the University first began to develop this area," said Zimmer. "Molecular engineering has been critical to expanding the University's capacity to contribute to science, engineering, and technology development, and to do so in a highly distinctive way."

Since receiving the Pritzker Foundation's gift, Pritzker Molecular Engineering faculty now number in the forties. In 2019, the school introduced a master of science in molecular engineering (MSME) program. The Chicago Immunoengineering Innovation Center (CIIC) launched in 2020. And a new program in partnership with City Colleges of Chicago welcomed its first cohort of students in 2021.

Looking forward, PME will continue to build programs in quantum engineering, biotechnology, immunoengineering, advanced materials, energy storage, and clean water technology. The school also plans to expand to address other fundamental problems and promote new collaborations among leading researchers from diverse science and engineering disciplines.

Ten years after its creation, PME stands as the thriving result of a single decision: whether to take the path of least risk or the one that is bold. That decision—the choice to be bold—resonates every day in the halls of PME, energizing it and propelling it onward.

PME AND ARGONNE NATIONAL LABORATORY SHARE FRUITFUL PARTNERSHIP

One critical key to the success of the Pritzker School of Molecular Engineering (PME) is its relationship with Argonne National Laboratory.

The national lab—located in nearby Lemont, Illinois—has been managed by the University of Chicago since the lab's inception in the 1940s. Originally created to explore peaceful uses of nuclear energy in the wake of World War II, Argonne has become a national leader in multidisciplinary research and advanced computing. The lab contains 16 research divisions, 12 centers, and six national user facilities, including the Center for Nanoscale Materials, the Advanced Photon Source, and the Argonne Leadership Computing Facility.

The creation of a program in molecular engineering presented an opportunity for the relationship between the University and Argonne to grow, fostering increased collaboration between the two institutions. In the ten years since Pritzker Molecular Engineering's inception, a great deal of research and ambitious new programs have emerged from this relationship.

For instance, many of PME's faculty—today around forty percent—have joint appointments with the University and Argonne. These appointments not only provide faculty access to the national lab's advanced facilities, but also help initiate new research projects and initiatives under Argonne's banner. At the same time, many Argonne scientists have formal affiliation with the PME through the UChicago Consortium for Advanced Science and Engineering (CASE) program, which allows them to better collaborate on research and engage with PME students, postdoctoral scholars, and faculty members.

Some notable programs to arise from the partnership, many of which are funded by the Department of Energy, include AI-enabled Molecular Engineering of Materials and Systems (AIMEMS), an NSF Research Traineeship (NRT) program that supports new models for graduate education; the Advanced Materials for Energy-Water Systems (AMEWS) Center, which studies interfaces between materials and water; Q-NEXT, a center dedicated to quantum technology; Duality, a quantum startup accelerator; and the Midwest Integrated Center for Computational Materials (MICCoM), based at Argonne and led by Liew Family Professor of Molecular Engineering Giulia Galli, who also holds the title of senior scientist at Argonne.

Also among recent developments is the University's Graduate Research Cooperative (GRC). This program allows PME graduate students to conduct large portions of their research in residence (up to five years) at Argonne. Related to that, for the first time, Argonne scientists, due to their CASE affiliation, can serve as primary research advisors for PhD students. These changes give students further access to highly specialized instrumentation and let Argonne researchers work closely with some of the country's brightest aspiring scientists.

That same collaborative dynamic extends to PME leadership, as well. From 2015 to 2018, Dean Matthew Tirrell also served as deputy laboratory director at Argonne. PME Professor Supratik Guha led the Center for Nanoscale Materials from 2015 to 2019 and is currently a senior advisor to the Physical Sciences and Engineering directorate. Then, in 2017, Seth Darling, a PME fellow, was named director of the Center for Molecular Engineering at Argonne (CME), which facilitates the relationship between Argonne and PME. And in August 2018, Juan de Pablo, Liew Family Professor in Molecular Engineering, was appointed as the University's vice president for national laboratories, a role which expanded in 2020 to also encompass science strategy, innovation, and global initiatives.

As PME continues to grow—it has plans to double its total number of faculty—its partnership with Argonne will also expand to include more joint-appointments, research projects, and student researchers. This continuously evolving relationship underscores the value the partnership provides to both institutions, one that uses convergent science and collaboration to address some of the most pressing issues of our time.

A TRANSFORMATIVE GIFT

On May 28, 2019, the University of Chicago announced a $100 million commitment from the Pritzker Foundation in support of its molecular engineering program, elevating the program to the Pritzker School of Molecular Engineering (PME) and making it the first school of its kind in the United States and the first new school at the University in three decades.

The gift has helped enable Pritzker Molecular Engineering to expand its faculty, degree programs, and technological capabilities, creating new options for students and researchers investigating molecular-level science. In the two years since the announcement, the school has made numerous advancements, notable among them being the expansion of its faculty; the creation of a master of science in molecular engineering (MSME) program; the launch of Duality, a startup accelerator program dedicated to quantum engineering; and a partnership to introduce City Colleges of Chicago students to pathways in STEM fields.

The announcement itself was given at UChicago's Gleacher Center with speeches from Chicago Mayor Lori Lightfoot; Foundation Chair and University Trustee Thomas J. Pritzker, MBA'76, JD'76; then-University President Robert J. Zimmer; and PME Dean Matthew Tirrell.

"The Pritzker Foundation has been committed to the idea of molecular engineering since the University first began to develop this area," said Zimmer. "Molecular engineering has been critical to expanding the University's capacity to contribute to science, engineering, and technology development, and to do so in a highly distinctive way.

The latest commitment of the Pritzker Foundation will support dramatic further expansion and long-term sustainability of the University's work in molecular engineering."

The Pritzker Foundation has long been a generous supporter of the University and was a crucial partner in the program's early development, helping to fund its founding directorship as well as the Pritzker Nanofabrication Facility.

"I became interested in molecular engineering nearly a decade ago when it was just a bold idea, recognizing the potential for the University to help build a new field of study," said Pritzker. "Molecular engineering could provide a disruptive approach to translational science, while supporting the continuing evolution of the University of Chicago and becoming a catalyst to make Chicago a center of excellence in scientific innovation. Under the leadership of University faculty and President Zimmer, that powerful idea is becoming a reality. Our early support provided resources to develop the initiative and recruit Matthew Tirrell as founding director. As molecular engineering at the University gained traction, we wanted to support the next exciting phase."

Thomas J. Pritzker, MBA'76, JD'76

Prof. Jeffrey Hubbell

ACCELERATING TIME TO MARKET

PME scientists enhance translational research and entrepreneurship at the University of Chicago

The University of Chicago's focus on translational science, the practice of turning basic science into practical solutions for human problems, took a step forward when the Pritzker School of Molecular Engineering (PME) came onto the scene.

By its very definition, engineering—the process of using scientific principles to create solutions—is a translational discipline. And many of the faculty who came to UChicago to build Pritzker Molecular Engineering hailed from institutions where translational research was commonplace.

For instance, Jeffrey Hubbell, Eugene Bell Professor in Tissue Engineering, came from the École Polytechnique Fédérale de Lausanne, a premiere engineering school in Switzerland.

Hubbell, who has founded several companies, said doing translational research at a university has wide-ranging benefits. It allows scientists to see if their idea, which may work in the controlled conditions of a lab, can actually have an impact in the real world. It gives students the opportunity to partner with industry collaborators and possibly land a job in industry after graduation. And it forces researchers to work harder to focus their ideas, thinking through whether an idea will actually solve a compelling problem and what the challenges of bringing it to the marketplace to serve human needs might be.

"As a PhD student, you want to spend your time on a problem that can have a positive impact on society and that can be tested," said Hubbell, also vice dean and executive officer at PME. "Thinking entrepreneurially helps you consider those implications: 'Does my research solve a pressing need that can be tested? If it works in the test, could it be turned into something that has societal impact?'"

/ Center helps future entrepreneurs

While Hubbell has experience spinning off companies out of his lab, he still appreciates the entrepreneurial advice that UChicago faculty, students, and alumni can get through the Polsky Center for Entrepreneurship and Innovation at the Booth School of Business, which offers mentorship, funding, connections, and other resources. In 2020, innovation activities at the Polsky Center came under the helm of Prof. Juan de Pablo when the University of Chicago appointed him its Vice President for National Laboratories, Science Strategy, Innovation, and Global Initiatives.

The center used to be focused solely on students interested in pursuing a career in venture capital and private equity. That changed in 2016 when new funding allowed the center to expand its mission to support all faculty who want to bring their ideas to market.

That expanded mission has been a boon for PME and its focus on translational science. In April 2021, for instance, the Polsky Center teamed up with the Chicago Quantum Exchange (CQE), the University of Illinois at Urbana-Champaign, tech nonprofit P33, and Argonne National Laboratory to launch Duality, the first accelerator program in the nation that is exclusively dedicated to startup companies focused on quantum science and technology.

"The accelerator will not only support the efforts of early-stage quantum startups to grow and bring their critical technologies and applications to the marketplace," said Liew Family Professor of Molecular Engineering David Awschalom, "but will also help to expand the ecosystem to include a more diverse and inclusive community and workforce."

/ Critical funding

The Polsky Center also manages the $20 million University of Chicago Innovation Fund, which invests in promising technologies and startups created by current faculty, students, and staff of the University and its affiliates, including Argonne National Laboratory, Fermi National Accelerator Laboratory, and the Marine Biological Laboratory.

A committee of industry experts—angel and venture capital investors, scientists, and entrepreneurs—gives feedback to anyone who applies for funds to help them move their projects forward. The fund provides capital investment when UChicago entrepreneurial projects are at a critical development point—beyond basic science and research grant funding, but still too early to attract corporate or venture capital funding.

Several PME researchers have benefited from the fund. In 2017, ClostraBio, a startup seeking to address food allergies by restoring healthy intestinal microbiota compositions, received $250,000. And in 2018, BiomeSense, a startup developing a fully automated biosensor for low-cost, scalable microbiome testing, received $250,000.

/ Immunoengineering leads the way

Hubbell and Melody Swartz, William B. Ogden Professor of Molecular Engineering, hope to see even more immunoengineering entrepreneurship through the 2020 launch of the Chicago Immunoengineering Innovation Center (CIIC). The center focuses on developing new technologies to treat diseases and, similar to the Innovation Fund, provides bridge grants to fill funding gaps in the research pipeline.

The CIIC is also working with the Polsky Center to help commercialize and license immunoengineering technologies.

In the future, Hubbell hopes to see translational research really take off at UChicago. He said PME's focus on convergent research, across disciplines, coupled with the business acumen of the Polsky Center, should help foster greater entrepreneurship.

"We at PME are helping to lead the charge," he said. "And the Polsky Center is there to glue it all together."

Prof. Supratik Guha

INCORPORATED STARTUPS

In partnership with the Polsky Center for Entrepreneurship and Innovation, PME faculty and fellows contributed to the creation of the following incorporated startups:

- **Arrow Immune**
- **BiomeSense**
- **ClostraBio**
- **Covira Surgical**
- **Evozyne**
- **HeioThera**
- **Kanyos Bio**
- **Nanocrystal Glue**
- **NanoPattern Technologies**
- **Phlaxis**
- **Quantitative Insights**

2007
Faculty committee recommends a formal program in molecular engineering

2010
University Senate, Board of Trustees endorses creation of program

2011
Matthew Tirrell joins as Founding Pritzker Director

2012
First faculty hired

2013
First Department of Energy supported projects with Argonne National Laboratory established

2014
Construction of the Pritzker Nanofabrication Facility announced

2015
The William Eckhardt Research Center opens

2019
Program elevated to the Pritzker School of Molecular Engineering

PME FOUNDING MILESTONES

AN INDUSTRY EDGE

*Q&A WITH **FELIX LU**, DIRECTOR OF CORPORATE ENGAGEMENT*

Felix Lu, Director of Corporate Engagement

Building industry partnerships is critical to the mission of the Pritzker School of Molecular Engineering (PME), driven by its desire to create tangible, market-viable solutions to today's most pressing issues. To foster those partnerships, the school established its Office of Corporate Engagement, which connects companies across the industry spectrum to the state-of-the-art facilities and cutting-edge research at PME. Felix Lu, director of corporate engagement, helps lead that effort.

What type of companies does PME partner with?

We partner with innovative companies—medical, industrial, technological, financial—that want to bridge their operations to future markets. We fit really well with companies that are looking at the future and asking how they can evolve. That could be companies looking at biomedical tools, advanced materials like sustainable plastics or skin-like electronics with embedded sensors, or it could be companies who want to leverage unhackable communication channels along with incredibly powerful quantum computers.

Robust and effective innovation takes effort. One of PME's biggest draws is that it attracts some of the most creative and capable global talent, actively encourages thinking beyond traditional disciplines, and pairs researchers with state-of-the-art instruments and access to national lab facilities.

How can companies partner with PME?

One option is to take part in senior capstone projects. These are good opportunities for partners to work really closely with some of the country's brightest emerging engineers over the entire 22-week span of their thesis project. It's a good way to get involved with the science and get to know the individual students.

Internships are another terrific option and one that's had a lot of success in the past. These present a chance for partners to see our students in action at industry facilities. We provide top-tier candidates, trained in a variety of disciplines so they're industry-ready right after they graduate.

We also have a robust selection of advanced instrumentation here at PME, which partners can pay to use. This is a good option if a company wants to test a process or a material and stay close to the analysis instead of hiring external help.

Sponsored research is the best option for partners who are ready to make a substantial investment in their research and establish a relationship with the school. This type of collaboration provides early access to experiment results, access to the experiment process, and a truly collaborative relationship with the graduate students and faculty. It's a big step, but one that generates big returns.

In addition to those options, we're also exploring a case-resolution workshop using crowd-sourced creativity where students from all over campus can come together to solve a problem assigned by a corporate partner.

Can you tell us about a recent successful partnership?

We've had a number of really successful partnerships to date. Those with 3M, DuPont, and Sight Machine are some of our more recent connections, and they've all given feedback about how PME graduates stand out for their ability to clearly explain the science to their peers and non-scientists.

Hollister Incorporated is a company that develops and manufactures healthcare products, and we've had a great relationship with them during my time here. They have worked closely with capstone projects and with the Polsky Center for Entrepreneurship and Innovation—which advances entrepreneurship and research commercialization innovation activities at UChicago through the creation of new ventures and partnerships—and are looking to collaborate even more. Because their products interact closely with a patient's internal physiology, they need to be made of specialized materials that can prevent infection. We've been working with Hollister to explore new materials that are antimicrobial and sustainable.

What's on the horizon for corporate engagement?

In 2021–2022, we're expanding our partnership road map and will be linking up with entirely new industry partners that align with each of our major research themes. It's a focused effort to get everyone back into action in the post-pandemic era, and I'm really looking forward to it.

30
INDUSTRIAL PARTNERS
SPONSORING RESEARCH

220
PATENTS
HELD BY FACULTY MEMBERS

134
INVENTION DISCLOSURES FOR PATENTS FILED
SINCE FOUNDING

THEMES

The Pritzker School of Molecular Engineering transcends traditional boundaries by organizing our research into convergent themes focused on issues that have an impact on humanity and quality of life. Current themes concentrate on quantum engineering, biotechnology and immunoengineering, advanced materials, energy storage, and ensuring a clean global water supply. Our distinctive approach brings together experts in diverse academic disciplines to examine and develop holistic solutions to complex problems.

TELLING THE SCIENTIST'S STORY

Arts, Sciences, and Technology theme uses theater and film to provide a window into science and the scientific process

The Pritzker School of Molecular Engineering (PME) set out to transcend traditional boundaries in engineering education and its Arts, Sciences, and Technology theme exemplifies this objective. With a stated mission to investigate science and technology through artistic exploration, this theme fosters the public's understanding of science via the power of storytelling.

At the helm of this theme is STAGE—Scientists, Technologists, and Artists Generating Exploration—a full-scale laboratory focused on meaningful collaborations among scientists and artists. The lab's distinct research focuses on the creation and development of stage plays, films, and multimedia/multidisciplinary productions—all designed to be emotionally engaging, entertaining stories rather than science lectures disguised as art.

Nancy Kawalek, Professor and Distinguished Fellow in the Arts, Sciences, and Technology, began heading up the initiative in 2013, bringing with her more than 25 years of professional experience in theater as an actor, writer, and director. To her, it's imperative that institutions like PME reach a broad swath of the public. To do this, they need to do more than simply rephrase science in plain language, she said. Instead, they must convey its human element, with all of the inherent emotions.

"If you want to make someone passionate about something, if you want to capture their attention, you have to offer them a visceral experience," she said. "That's the greater goal, to really get people excited about science in this way. And there are so many good stories that come out of science, stories we hardly ever see that are captivating. That's what we want to focus on with STAGE."

/ A quantum dilemma

One of those stories is that of former University of Chicago Department of Physics graduate student Nathan Earnest-Noble. While a postdoctoral scholar in the STAGE Lab, Sunanda Prabhu-Gaunkar filmed Earnest-Noble as he worked to build a device that he hoped would be integral to quantum computing.

Throughout the film, Earnest-Noble confronts the emotional realities of scientific research—repeated failure, flagging motivation, lack of time—and must ultimately decide whether to publish partial findings or leave graduate school without publishing anything at all.

The film is the first installment in a series of short films, titled *Curiosity: The Making of a Scientist*, that follow scientists as they navigate the daily struggles of their work. Subsequent installments are slated for release in 2021 and 2022.

Prabhu-Gaunkar, who began her postdoctoral work in 2017 and became the director of science for STAGE in 2020, conceived of the project as one that would portray the full spectrum of scientific endeavor.

"The scientific process inspires our filmmaking," Prabhu-Gaunkar said. "The workflow embraces failure, remains receptive to discoveries through iteration, and allows for risk-taking, all within a highly collaborative process."

/ Inspiration and imagination

The exploratory process of experimental science, with its continuous analysis and feedback, also serves as the inspiration for STAGE's work process on theater projects. For instance, STAGE uses improvisation to generate and investigate new ideas. Kawalek explains that each spontaneous exercise is weighed and examined for what it reveals. Just as scientists analyze their results and use that information to revise an experiment, the most powerful material that emerges from improvisations guides the creation of the script, she said, and the ensuing performances.

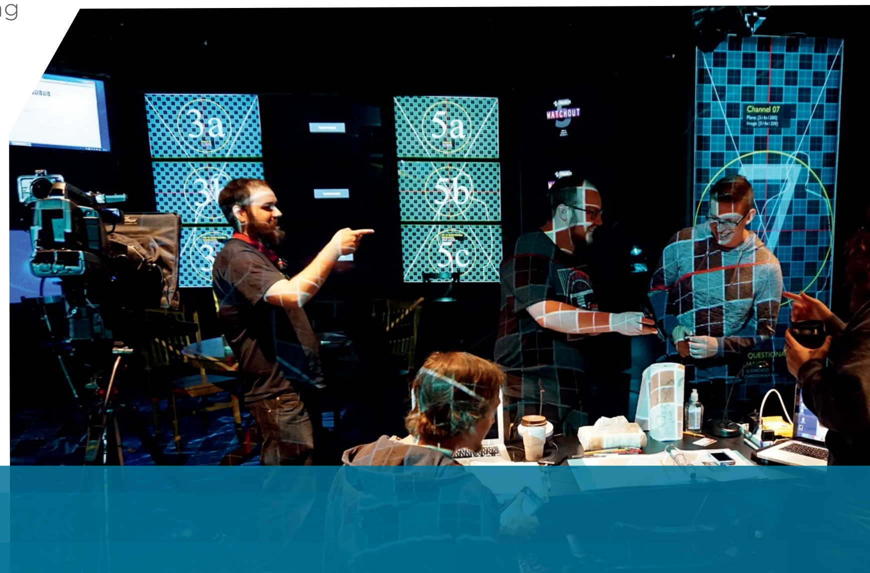
The group works on at least two or three projects at once, and the topics vary widely. One upcoming story about artificial intelligence, called *The Information Palace*, is inspired by two real-life circumstances: an early 20th-century treatise that was, in many ways, a precursor to the Internet, and advances in data science that are currently being used to find out precisely who revealed the hiding place of Anne Frank, her family, and their friends to the Gestapo in 1944.

Another is *Bend, Fold, Break*, about a young Japanese American scientist, a postdoctoral scholar researching DNA folding. The science of DNA folding is integrated into a story about identity, heritage, and culture. As with STAGE's other theater work, cinematic effects and new technologies are prototyped and integrated into the storytelling and staging throughout the development process.

/ Incorporating data sets and storytelling

University faculty, particularly from the PME, often collaborate on STAGE projects. PME Prof. Supratik Guha's Water-to-Cloud (W2C) project in India inspired *The River Project*, which is also currently in development. W2C uses sensor technology to measure the pollution of India's rivers in real time. In tandem with the scientific study, Prof. Surajit Sarkar's team at Ambedkar University Delhi's Centre for Community Knowledge has been investigating the impact of river pollution by interviewing riverine communities.

With the help of a Global Faculty Award from the UChicago Center in Delhi, STAGE is immersing itself in both data sets (the scientific research and the interviews) to create and develop a human story about threatened water supplies, scientific means of addressing the seriousness of the situation, and the people whose lives are inextricably linked to the rivers.



/ Entangling the past and present

Perhaps the most ambitious story that STAGE collaborators hope to tell is titled *Entanglement*, which, in part, aims to explore quantum entanglement with motion capture technology and kung fu.

Kawalek was inspired to undertake the project after seeing work by new media artist Jeffrey Shaw, in which motion capture and other cutting-edge technologies were used to map the movements of martial artist Oscar Lam onto an avatar of his long-deceased great-grandfather, kung fu master Lam Sai Wing. The digital wizardry of Shaw and his team essentially brought the late kung fu master back to life, enabling the culture and traditions of martial arts and of Hong Kong to be preserved, communicated, and passed down to future generations.

In its meaning, "kung fu" (功夫) conveys the notions of energy and time. Energy and time are two fundamental concepts in science, and in PME Asst. Prof. Tian Zhong's research on quantum entanglement. Zhong is a collaborator on the project, which is currently in development, with production planned in 2022.

Kawalek received a UChicago Global Faculty Award from The Hong Kong Jockey Club University of Chicago Academic Complex, which enabled the STAGE lab group to travel to Hong Kong to conduct a research workshop with Shaw, martial artist Oscar Lam, and their team. Since the start of the pandemic, further research, workshops, and project development have been conducted remotely.

As the play develops, Zhong said he hopes it will increase public awareness and knowledge about quantum science, especially among younger generations.

"The avatar of Lam Sai Wing represents a collapsing of time, spanning two generations through movement," he said. "This is exactly the essence of time-energy entanglement, so we thought this was a perfect way to inform an audience about the concepts of quantum physics.

"These connections between science and art—at some level, they're about the same thing," Zhong said. "Both start with asking intriguing questions. Then you use existing knowledge to inquire and explore, and the outcome is creation—new knowledge or new art. It's just the toolsets that are different."

/ Center STAGE

Kawalek has big plans for STAGE's future. Most immediate are a slate of projects that will explore new storytelling mediums, including a collaboration with Freckled Sky, a multimedia production company specializing in new technologies for live performance.

Prabhu-Gaunkar is about to release another episode of *Curiosity*, this time featuring UChicago's Erin Adams, Joseph Regenstein Professor in the Department of Biochemistry and Molecular Biology. STAGE is also producing a series of recruitment videos for the quantum workforce as part of an NSF grant. The videos are designed to spark interest in historically underrepresented communities.

Beyond productions, Kawalek plans to ultimately elevate STAGE to a center based at the University of Chicago, and in doing so, increase the public's appreciation of science and elevate the convergence of art and science.

"Given the growing, widely publicized debate between scientific fact and fiction, and scientists' awareness of their own challenges in communicating their work more effectively and their hunger to do so, I don't think it's an exaggeration to say there's a dire need to promote understanding of the sciences," said Kawalek, adding: "Science has everything that makes for good drama—passion, intrigue, despair, high stakes—so as subject matter, it's ideally suited to theater and film. Science illuminates how the world works, and art illuminates how people work. The two disciplines are a perfect match."

ENGINEERING THE IMMUNE SYSTEM FOR BETTER HEALTH

PME Immunoengineering faculty strive to understand the immune system from top to bottom and to create tangible methods for improving human health

In 2014, Jeffrey Hubbell and Melody Swartz left their posts at Switzerland's École Polytechnique Fédérale de Lausanne to join the faculty at the Pritzker School of Molecular Engineering (PME). Hubbell brought with him dozens of patents and a deep research record that included investigations into tissue engineering and nanoparticle vaccine delivery. Swartz, a MacArthur Fellow, came with a long CV filled with citations around the role of the lymphatic system in cancer and engineering approaches to immunotherapy.

Together, the two helped launch Pritzker Molecular Engineering's third theme—Immunoengineering—with an eye toward becoming one of the top programs in the nation. The school has since hired 14 additional faculty members who focus on using engineering tools to unlock the secrets of the immune system and manipulating it to achieve better human health.

"Scientists have learned a tremendous amount about how the immune system works," said Hubbell, Eugene Bell Professor in Tissue Engineering, "but many challenges remain."

/ A different view

One of those challenges is to understand how the immune system works at the level of a single cell or molecule. Several of PME's Immunoengineering faculty members focus their research in that area, including Asst. Prof. Nicolas Chevrier who seeks to understand how the immune system functions from the molecular levels in organs, across organs, and finally throughout entire organisms.

Another, Asst. Prof. Jun Huang, employs cutting-edge techniques such as single-cell omics—high-throughput analyses of the genomes, transcriptomes, and proteomes of single cells—and single-molecule microscopy to examine how individual cells come together to regulate the function of a tissue or an organ.

A different immune system challenge that scientists have long grappled with is understanding the spatial orientation of molecules and genes within a cell. Asst. Prof. Joshua Weinstein has helped create a highly novel approach to solving that problem. He led the development of a new technique called DNA microscopy, which uses chemical reactions to show the interior of a cell, illuminating the spatial locations of specific genes. The technique can show which immune receptor genes inside a cell are active and whether particular cells are healthy or have tumor-causing mutations.

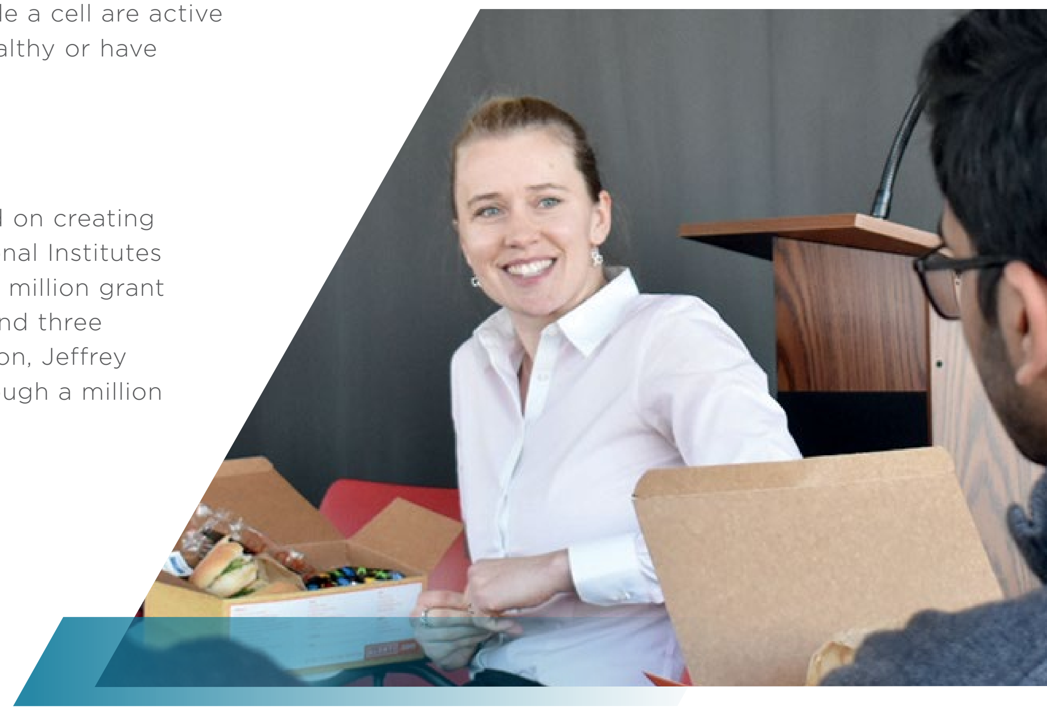
"Faculty members use engineering tools to unlock the secrets of the immune system and manipulate it to achieve better health."

/ A shot in the arm

Other faculty members are focused on creating new and better vaccines. The National Institutes of Health recently awarded an $8.6 million grant to Assoc. Prof. Aaron Esser-Kahn and three other PME faculty—Andrew Ferguson, Jeffrey Hubbell, and Savas Tay—to sift through a million molecules to find the few that have the potential to be vaccine adjuvants—substances added to a vaccine to stimulate the immune system to respond to them. In this case, the researchers especially want to find adjuvants that inhibit inflammation, which can sometimes occur when a vaccine is given. Such inflammation can actually reduce vaccine effectiveness.

"This is my lab's most ambitious project to date," said Esser-Kahn. "Our hope is that within the first two years we will have found interesting candidates through screening, and then we can use the next three years to develop what we found."

Both Hubbell and Swartz, William B. Ogden Professor of Molecular Engineering, also do vaccine work. Hubbell creates "inverse vaccines" that instead of turning on the immune system to fight a pathogen, are engineered to turn off or quiet an immune reaction to help patients with autoimmune disease.



2014 Jeffrey Hubbell, Melody Swartz

2015 Jun Huang

2016 Savas Tay

2017 Nicolas Chevrier, Aaron Esser-Kahn, Rama Ranganathan

2018 Andrew Ferguson, Juan Mendoza

2019 Margaret Gardel, Mark Mimee, Cathryn Nagler, Samantha Riesenfeld, Allison Squires, Joshua Weinstein

2020 Huanhuan Joyce Chen

IMMUNOENGINEERING FACULTY

"We've shown efficacy in mouse models of two autoimmune diseases—type 1 diabetes and multiple sclerosis," said Hubbell. The technology is now being used in Phase 1 clinical investigation to test its effectiveness in humans with multiple sclerosis and celiac disease.

Swartz, meanwhile, has developed a new therapeutic vaccine that uses a patient's own tumor cells to train their immune system to find and kill cancer.

"This cellular vaccine has the potential to be more efficacious, less expensive, and much safer than many other immunotherapies," said Swartz.

/ Crunching data

As with so many systems in the body, there are vast amounts of data points within the immune system, so the Immunoengineering faculty employ artificial intelligence techniques such as machine learning to speed up the process. For instance, Assoc. Prof. Andrew Ferguson uses machine learning to search for the soft spots within a virus's genome and then design T cell immunogens to target these vulnerabilities.

And Asst. Prof. Samantha Riesenfeld uses computational approaches to identify factors that shape immune responses. She recently discovered that certain immune cells unexpectedly change their behavior to instigate psoriasis lesions—an insight that could ultimately lead to better treatment of the chronic inflammatory skin disease.

"These findings tell us something new, both about how psoriasis arises and about how an inflammatory trigger can change the behavior of immune cells," Riesenfeld said. "We now think about the identities of the particular cells we studied as more flexible and less predetermined than we used to. That is, cells that are predisposed to play one role may do something very different under duress."

/ Continued growth in human immunology

Hubbell and Swartz say the future of the program will be one even more focused on the science, technology, and medicine involved in human immunology.

"We are an engineering school that is located a stone's throw away from a renowned medical school," said Hubbell. "So, we would like to hire faculty who benefit strongly from that proximity and the availability of clinical samples and availability of patients."

Both Hubbell and Swartz have a long history of doing translational research—taking scientific ideas and turning them into applicable things such as new methods to diagnose disease and new drugs. And they want PME's Immunoengineering to follow that path.

"Translation is definitely a key objective of ours," said Hubbell. "It's not the only objective, but it's a key one."

A CENTER TO DRIVE TRANSLATIONAL SCIENCE

After two years of planning, the Chicago Immunoengineering Innovation Center (CIIC) opened in February 2020 to catalyze fundamental and translational research in immunology so the treatments developed from them can be used to improve human health.

"We want to build more connectivity between the technologies and approaches that we're developing in PME's Immunoengineering labs with the actual patients in a hospital setting," said Jeffrey Hubbell, Eugene Bell Professor in Tissue Engineering, who co-directs the CIIC with Melody Swartz, William B. Ogden Professor of Molecular Engineering.

As part of this strategy, the center provides bridge funding to help fill holes in the immunoengineering research pipeline. During the height of the coronavirus pandemic, this funding model also allowed the center to quickly apply for stimulus funds to start new projects focused on COVID-19, with the eventual goal of attracting external support through grants or industry partnerships.

The center has core facilities that researchers can use, including preclinical evaluation and single cell genomics core facilities. It also contains a mouse clinic with many different disease models—cancer, autoimmune diseases, inflammatory models—that allows researchers to test their ideas in an animal model, an important step to attract potential funders to move toward human trials.

6

INDUSTRIAL PARTNERS

SPONSORING RESEARCH AT CIIC

"To go from a basic idea to showing your results in a mouse model is a key next step for translation," said Hubbell. "That can sometimes be a million-dollar undertaking, so we created this mouse clinic so that we can really efficiently test ideas in animal models of disease."

The center's faculty span several schools and departments at the University of Chicago and approach immunoengineering from a number of collaborative angles, such as cancer immunotherapy, vaccine delivery, the role of the microbiome in allergies, and autoimmune disorders.

"Because we have so many research teams working in this area, we are able to really build off and learn from each other," said Swartz. "The discoveries you make in cancer immunotherapy, for example, can be valuable in treating autoimmune diseases. This center will make those cross-lab connections even stronger."

The center also works closely with the immunoengineering startup community, Argonne National Laboratory, and UChicago's Polsky Center for Entrepreneurship and Innovation to commercialize and license technologies.

"We hope to be the ideas engine that helps build a bigger biotechnology startup culture in Chicago," Hubbell said. "We want to push our technologies out the door, and we want to see measurable results in terms of patents and licenses."

DISCOVERY LEADS TO THRIVING STARTUP

Cathryn Nagler, Bunning Family Professor, worked in her laboratory for more than 30 years, trying to understand the physiological origins of food allergies and potential treatments. Not once did she consider translating that research into a business. But after some startup microbiome companies expressed interest in using her lab to test their microbiome-based drugs, University of Chicago donors and colleagues encouraged her to instead start her own company. So she did with the help of Prof. Jeffrey Hubbell, a serial entrepreneur who arrived at the University in 2014. Hubbell, Eugene Bell Professor in Tissue Engineering, had founded several companies and had a deep understanding of the kind of research that can translate into a real-world setting.

Nagler had made a significant discovery in 2014, identifying a key population of bacteria in mice that appeared to be creating a protective barrier that stopped allergens from entering the bloodstream.

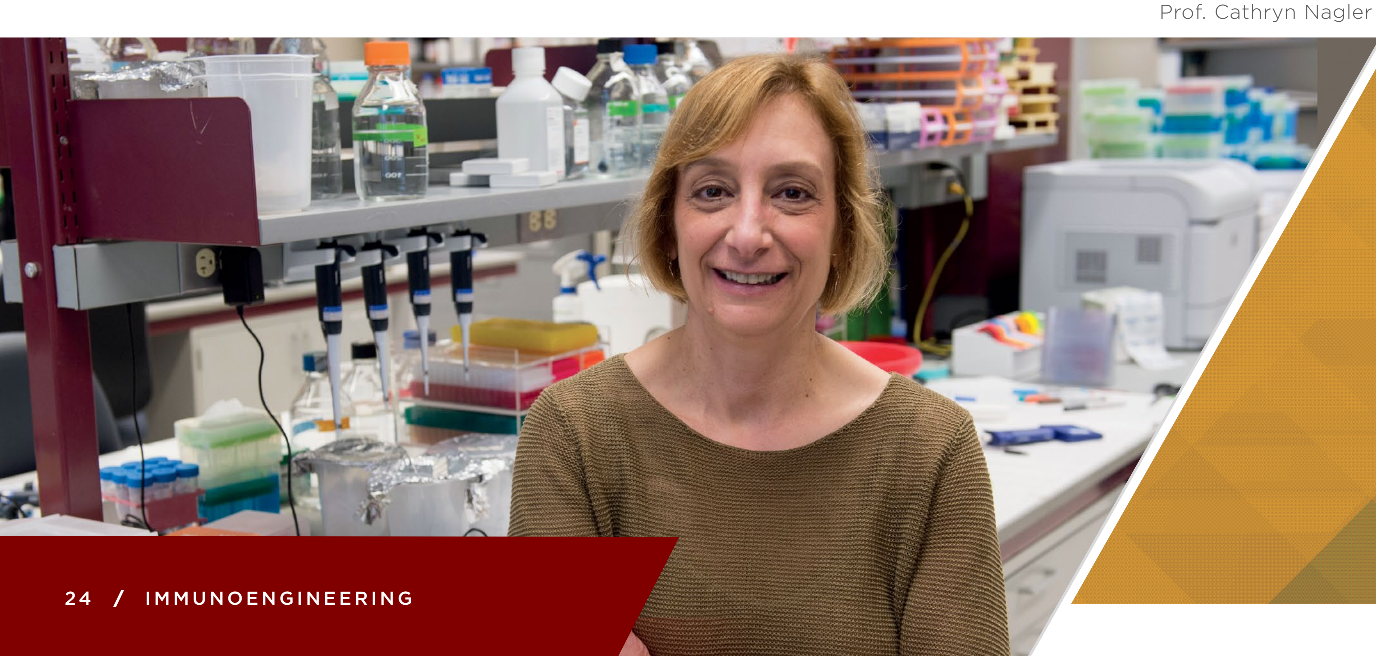
With Hubbell's engineering skills, they were then able to create a synthetic version of one of the products of those bacteria. Hubbell also created a specialized delivery system for the bacterial product, so once ingested, it would only activate in the gut—making it a very targeted therapeutic with fewer side effects.

Still, the two needed help from experts to get their product on the market so it could help patients. They first worked with UChicago's Polsky Center for Entrepreneurship, where Nagler learned, among other things, how to pitch to potential donors.

From there, they turned to Chicago's first private equity firm centered around bringing life science inventions to market—Portal Innovations. The company, which launched in May of 2021, invested in Nagler and Hubbell's startup, named ClostraBio. It also provided the two scientists with the expertise to navigate the complicated world of FDA approval and human drug trials.

Staff for Nagler, Hubbell, and Portal are now going through the first significant round of venture capital funding for ClostraBio with the hope of raising at least $25 million so that clinical trials can begin in 2022.

"It's a very exciting time," Nagler said. "This company feels like the capstone of my career."



Prof. Cathryn Nagler

Prof. Melody Swartz

SUPPORTING THE FUTURE OF IMMUNOLOGY RESEARCH

Bruce Herzfelder, MBA'87, JD'87, knew he wanted to support the Pritzker School of Molecular Engineering (PME) after he heard Melody Swartz, the William B. Ogden Professor of Molecular Engineering, speak about cancer immunotherapies as part of the Harper Lecture series in 2018. The series, put on by the University of Chicago Alumni Association, gives some of the University's brightest researchers a platform to showcase their work for alumni and industry representatives.

"I was blown away by her presentation," Herzfelder said. "That lecture was my introduction to immunoengineering, and it really instilled in me this sense of optimism—that Melody's work could lead to great outcomes. What's more is that she explained it all with a level of clarity and urgency that resonated with me. I knew then that I wanted to support what she was doing."

Swartz's research focuses on gaining a deeper understanding of how the lymphatic system regulates immunity in homeostasis and disease, particularly in cancer and chronic inflammation. Her lab applies that knowledge to develop novel immunotherapeutic approaches to cancer, including lymph node–targeting vaccines.

Herzfelder, the president and founder of BetterVet and previously of VetCor, began making annual donations to Swartz's lab shortly after the lecture. He specified that the donations should be used at Swartz's discretion, allowing the funds to be applied where she needs them the most.

"Gifts like Bruce's are crucial to moving scientific discovery forward," Swartz said. "Our line of research is dynamic, so having the freedom to apply a gift wherever it's needed makes a real difference."

As a University of Chicago alumnus, Herzfelder has long been a proponent of establishing an engineering program at the University, and he believes that PME and Swartz are poised to make great strides in the years to come.

"It's been exciting to be a part of the Pritzker School of Molecular Engineering's first 10 years," he said. "And I look forward to seeing its impact grow even more over the next 10 years and beyond."

LIVING IN A MATERIALS WORLD

PME faculty in the Materials Systems for Sustainability and Health theme design substances to make the earth cleaner and our bodies healthier

Pritzker School of Molecular Engineering (PME) faculty wanted to find a distinct focus for the program's materials theme that would set it apart from its peers.

"The field of materials science and engineering has a long and storied history," said Stuart Rowan, Barry L. MacLean Professor of Molecular Engineering Innovation and Enterprise. "So the question was, 'Can we at PME think about materials research in a different way?'"

Pritzker Molecular Engineering landed on the idea of focusing on two broad areas within materials science—health and sustainability—and hired a dozen faculty to help shape the theme.

"A strength that we have is a molecular understanding approach of how a material works, but always with an eye toward what you can apply it to, and to whether it's a health issue or a sustainability issue," said Rowan. "Knowing how a material works at the molecular level helps us predict how it will behave if it were used for a specific application, such as the ion-conducting membrane in a battery or a drug delivery system in the body."

/ Collaborating on polymer design

That molecular approach can be found in a range of areas that PME faculty study, from water filtration to smart windows to wearable electronics. Rowan's lab, for instance, is working to create greener plastics using bio-based cellulose nanocrystals (CNCs). Cellulose is a main building block of plants; CNCs can be obtained directly from the biosource and can be used to strengthen other materials.

As with many things at PME, this research is convergent in nature. Rowan is collaborating with other PME faculty such as Paul Nealey, Brady W. Dougan Professor of Molecular Engineering, and Asst. Prof. Shrayesh Patel on using CNCs in ion-conducting membranes for energy applications; and Dean Matthew Tirrell on how CNC composites can be used in water management applications.

"We're starting to build a cluster of folks who see an opportunity from different perspectives and bring different skill sets to the table, and this allows us to think about polymer design in a slightly different way," Rowan says. "This interface of disciplines is really exciting."

/ Taming big data

In the past, materials scientists spent a great deal of time formulating and testing different substances. Now computation techniques allow them to simulate the characteristics and behaviors of materials in specific applications.

PME has a strong team of researchers in this area, including Assoc. Prof. Andrew Ferguson and Rama Ranganathan, Joseph Regenstein Professor, who recently used machine learning to develop a recipe for building artificial proteins. And Juan de Pablo, Liew Family Professor of Molecular Engineering, recently created a database to train a machine-learning network to predict the properties of polymers.

Giulia Galli, also a Liew Family Professor of Molecular Engineering, has contributed to making materials research data accessible by creating the open source software Qresp, which facilitates the organization, annotation, and exploration of data presented in scientific papers. The software should make it easier for materials scientists to verify the reproducibility of their studies.

/ Green materials

Machine learning is also part of the work of Chibueze Amanchukwu, Neubauer Family Assistant Professor of Molecular Engineering, who is designing and synthesizing novel electrolyte media to boost battery performance. It's Amanchukwu's hope that with more efficient batteries, he and his team can help address climate change, a problem that is expected to impact developing countries, such as his native Nigeria, the most.

"As someone from Nigeria, I realized that any technology we make needs to be scalable and translatable to people back home so that we present a united front against climate change challenges and leave no one behind," he said.

Over the past decade, Galli and her group have developed new theoretical and computational tools to predict the properties of optimal materials for photovoltaics and photoelectrochemical cells, which hold promise for the next generation of renewable energy.

Also with an eye toward sustainability, Laura Gagliardi, Richard and Kathy Leventhal Professor, develops novel wave function–based quantum chemical methods and applies them to study problems related to renewable energies. She explores molecular systems and materials relevant to catalysis, carbon dioxide separations, photochemical processes, spectroscopy and heavy-element chemistry. She is also working on a project aimed at designing reticular materials that convert dry air into drinkable water.

/ Water sustainability

Junhong Chen, Crown Family Professor of Molecular Engineering and lead water strategist at Argonne National Laboratory, and colleagues recently received $2 million in funding to develop an artificial intelligence–assisted system for recovery of energy, nutrients, and freshwater from municipal wastewater. The resulting resource recovery system would benefit the water supply in underserved communities on Chicago's South Side as well as the Great Lakes region in general, including Milwaukee and Detroit.

"Our future economy and national security greatly depend on the availability of clean water," said Chen.

Galli researches the fundamental properties of water. She develops computational procedures for simulating the behavior of aqueous solutions at the molecular level and to understand the interaction of water with surfaces.

"One active area of research is to use catalysts to degrade pollutants in water, and to disinfect water," said Galli, who serves as deputy director of the Energy Frontier Research Center at Argonne, which focuses on advanced materials for energy-water systems. "That catalytic reaction will happen at an interface, so understanding that reactivity at the interface between the catalyst and water is important."

Asst. Prof. Chong Liu is developing materials for electrochemistry in order to extract natural resources from the ocean, such as lithium, which the world will need in greater and greater amounts to build the batteries for electric cars and to store wind and solar power.

"Seawater is the ultimate goal," Liu said. "Once we can do that, other sources with higher concentrations of lithium and other elements will be less challenging."

/ Elastic electrodes

In the human health sphere, Asst. Prof. Sihong Wang recently helped design stretchable sensors that have the potential to be used to detect the body's signals—ranging from chemical and electrical pulses to mechanical shifts—and use those cues to control various functions,

In the past, such sensors were made of brittle, inorganic material that didn't stretch with the skin or organs. Wang and colleagues solved this problem by incorporating a patterned material that optimizes strain distribution among transistors.

They used the same concept to design and fabricate other circuit parts such as a stretchable amplifier that is capable of amplifying faint electrophysiological signals—down to a few millivolts. That's important for sensing the body's weakest signals, like those from muscles.

"This new design allows electronics to stretch without compromising data and could ultimately help lead us to an out-of-clinic approach for monitoring our health," Wang said.

Prof. Juan de Pablo

/ Color-changing sensors

Human health could also be improved through the development of materials that can perform functions in response to changes in the environment: a capsule implanted in the body that automatically releases antibodies in response to a virus, or clothing that senses and captures toxic contaminants from the air.

Scientists and engineers have already taken the first step toward these types of autonomous materials by developing "active" materials that have the ability to move on their own. Recently, de Pablo and colleagues took the next step by showing the movement in one such active material—liquid crystals—can be harnessed and directed.

To do that, they added substances to the liquid crystals—actin filaments, the same filaments that constitute a cell's cytoskeleton and motor proteins, which exert force on the filaments—essentially "walking" along the filaments, causing the crystals to move. The proteins are light sensitive, so when the researchers shined a laser on certain parts of the liquid crystal, those regions became more active.

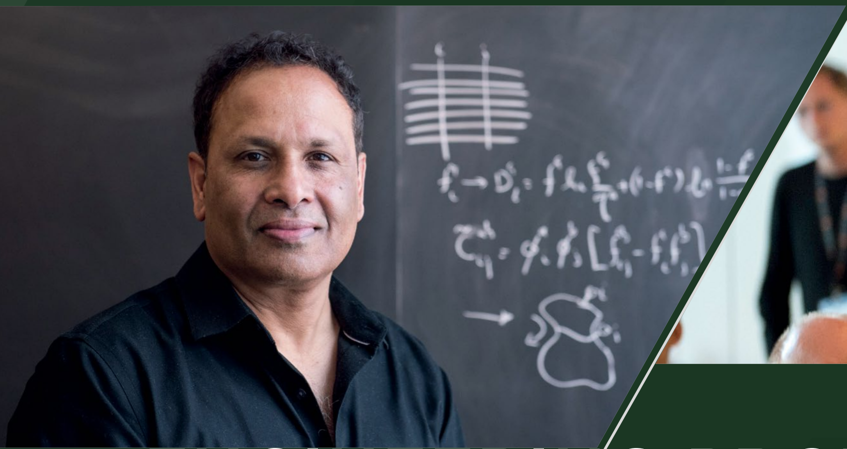
"In this work we have shown how to control these materials, which could pave the way for applications," de Pablo said. "We now have an example where molecular-level propulsion has been harnessed to control motion and transport over macroscopic scales."

Rowan believes the sky's the limit for the future of materials science at PME. "There are so many directions that it could go," he said. Materials engineering is part of every theme under PME's roof. Quantum engineers need precision materials to make qubits, the fundamental building block for quantum information processing, and immunoengineers want nanopolymers to carry drugs to different parts of the body.

"I love the fact that I go to my group meetings and one person is talking about the challenges of sustainable plastics, then the next person is talking about how we can engineer the immune system by using polymers, and the next person is talking about energy storage," said Rowan. "Having expertise in polymers allows us to help develop solutions to many challenges that have a global impact."

MATERIALS SYSTEMS FOR SUSTAINABILITY AND HEALTH FACULTY

2011 Matthew Tirrell
2012 Juan de Pablo, Paul Nealey
2013 Giulia Galli
2014 Jeffrey Hubbell
2015 Monisha Ghosh, Supratik Guha
2016 Shrayesh Patel, Stuart Rowan
2017 Aaron Esser-Kahn, James Skinner (retired 2020)
2018 Andrew Ferguson, Chong Liu, Sihong Wang
2019 Junhong Chen, Margaret Gardel
2020 Chibueze Amanchukwu, Laura Gagliardi, Dmitri Talapin
2021 Paul Alivisatos



Prof. Rama Ranganathan

Assoc. Prof. Andrew Ferguson

ENGINEERING PROTEINS TO HELP HUMANKIND

Proteins perform countless biological functions crucial to life, from helping humans digest food to helping plants convert light to energy. Scientists have long dreamed of harnessing the power of proteins to better humankind, but doing so has been tricky due to the absence of good models and design principles by which to guide their rational engineering.

Recently, researchers in the Pritzker School of Molecular Engineering (PME) have applied machine learning algorithms to large databases of protein sequences to learn the basic rules of protein structure and function. They then developed mathematical models based on these data to design synthetic proteins, never before produced by nature, with new structure and function.

"We found a very powerful method to distill nature's rules for proteins that also allows us to go backward and say, 'How do we make new proteins that follow these rules?'" said Assoc. Professor Andrew Ferguson.

Ferguson and colleague Rama Ranganathan, Joseph Regenstein Professor, recently co-founded a company called Evozyne (www.evozyne.com) to commercialize their method. Three PME alumni now work at the company, including Joshua Moller, PhD'20.

"My primary role is to create these deep learning models that suggest new proteins that we think have improved functionality," Moller said. "So I send off protein sequences to the lab; they then run them in the lab and send that information back to me, and I will, in turn, try to suggest new ones that I think would work better, given the information that they've provided."

> **"How do we make new proteins that follow these rules?"**

Evozyne recently entered into an agreement with Takeda Pharmaceutical Company Limited to develop artificial enzymes that could be used to treat patients born with enzyme deficiencies that cause the buildup of toxic materials in the body.

That project is one of many that Ferguson and Ranganathan hope to undertake. Others include developing synthetic proteins to create greener material and energy sources, and finding solutions to agricultural problems in order to feed more people sustainably.

Said Ferguson: "We want to go after high-impact applications that could really make a big difference."

ADVANCING APPLIED SCIENCE

For Bill Parker, MBA'78, the creation and rise of the Pritzker School of Molecular Engineering (PME) fulfilled a decades-long dream: that the University of Chicago establish an industry-leading engineering program.

"An idealistic young alum who emerged from his studies determined to help his alma mater, I learned that, of the avenues for growth and future financial security, there was one that the University had yet to explore," Parker said. "It struck me that an engineering program—the right engineering program—might one day serve the University in a number of useful ways."

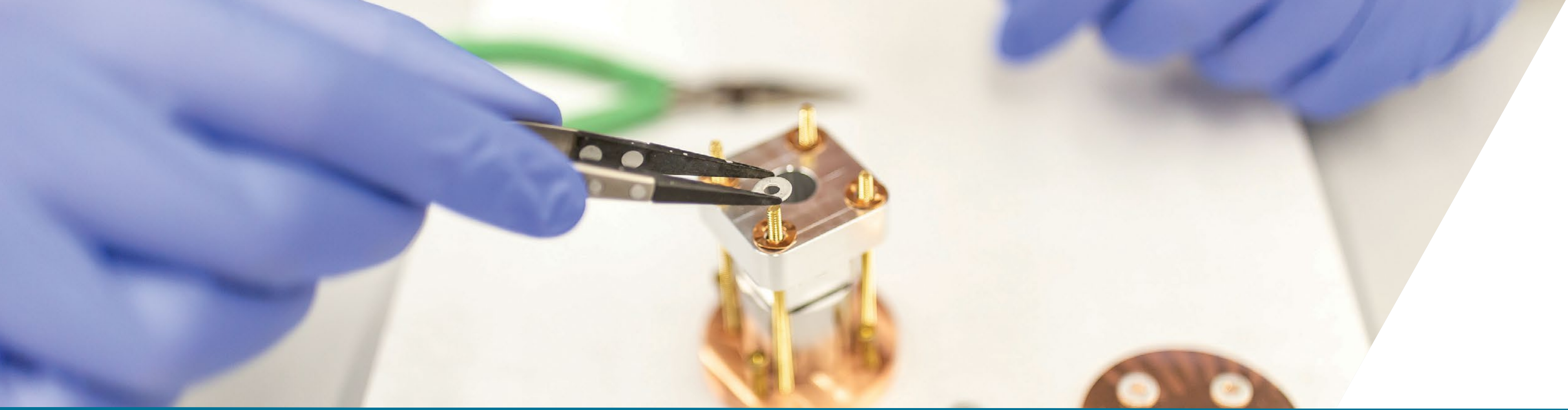
Energized by his realization, Parker urged University leadership to create such a program, and since the launch of Pritzker Molecular Engineering in 2011, he has been one of its most loyal and enthusiastic backers. For many years, Parker has supported the school through regular contributions to its annual fund, which strengthens the school today, and he has designated future support for PME through a bequest intention.

For Parker, PME's rise was the realization of a dream but, at the same time, it represented more—an opportunity for something greater.

Immunoengineering is a field that applies engineering principles to immunological research in order to develop treatments for autoimmune disease. Immunoengineering also happens to be one of PME's main research themes—and it's a field that hits close to home for Parker. His late wife, Gudrun, suffered a great deal from rheumatoid arthritis, a condition for which there is no cure. Immunoengineering presents an opportunity to change that.

"After having been with her through all the pain that she endured, I felt that no human should ever have to undergo anything like that," Parker said. "I look to molecular engineering to one day come up with an answer."

Ten years into its mission, PME is primed to deliver just what Parker hopes: insights and answers into many of today's most pressing issues. With his support and the support of others like him, a future with entirely new options for treating rheumatoid arthritis is that much closer to reality.



QUANTUM ENGINEERING HARNESSES THE POWER OF SMALL

By studying and applying the science of how atoms and subatomic particles behave, PME scientists will help usher in the quantum revolution

In 2013, when David Awschalom arrived at the University of Chicago's Pritzker School of Molecular Engineering (PME), he had his marching orders: build the first quantum engineering program in the United States.

As a professor of physics and electrical and computer engineering at the University of California, Santa Barbara; director of multiple research institutes; and an internationally recognized researcher, Awschalom was ready for the challenge of creating a program dealing with quantum physics—a counterintuitive field that concerns the behavior of matter and light on the atomic and subatomic scale.

29
CORPORATE PARTNERS
AT CQE

"Quantum physics was moving rapidly from fundamental science into the application space, and it was clear the country would need to create a quantum-ready workforce," said Awschalom, Liew Family Professor of Molecular Engineering. "Joining PME was an opportunity to build a new applied science program, help shape an emerging engineering discipline, and do something fundamentally different."

/ A truly collaborative effort

Within a few years of his arrival, Awschalom and Pritzker Molecular Engineering founding members had hired more than a dozen PME faculty in major areas of quantum engineering, such as sensing, communication, and computing. They also established partnerships with industry, national labs, and nearby universities. Additionally, in 2017, Awschalom launched the Chicago Quantum Exchange (CQE), an intellectual hub for the research and development of quantum technology.

All of these initiatives have helped establish UChicago and the Chicago area as a leader in quantum science and technology, positioning the region to possibly become the Silicon Valley of the field. Awschalom says the unique collection of partnerships—with a host of universities and national labs, more than two dozen corporate partners, and numerous non-profit and international partners—has already allowed some impressive breakthroughs in the field.

"We wouldn't be where we are today without recruiting the best faculty in the world, who are excited to work in this highly collaborative fashion with colleagues in industry and government," Awschalom said. "None of us can solve the technical challenges alone—industry, academia, and government need to work together to deliver on the promise of quantum science."

PME faculty focus broadly on emerging areas of quantum information science and engineering. One technology that could change the world is qubits, a basic unit of quantum information that powers quantum computing. Storing and wielding information in qubits, however, requires precise control of the underlying materials, and PME researchers are busy studying and testing different substances to find the best materials.

/ Unhackable communications

Experts say quantum will change the world in myriad ways, from providing unhackable encryption for communication to MRI technology that could probe the structure and the functional relationship of proteins in the body.

The former—unhackable encryption—took one step toward becoming a reality recently when PME and Argonne researchers created a quantum communications loop consisting of a pair of connected 26-mile fiber-optic cables that wind circuitously between Argonne and the Illinois Tollway near suburban Bolingbrook.

At 52 total miles, it is among the longest ground-based quantum communication channels in the country, and it will soon top that record with an extension that reaches all the way to UChicago and Hyde Park. The Chicago quantum network will serve as a testbed for researchers interested in leveraging the principles of quantum physics to send unhackable information across metropolitan distances.

"Inaugurating this quantum network is a significant step for Chicago and the nation in building a large-scale quantum network that can enable secure data transmissions over long distances," said Awschalom, also a senior scientist in the Materials Science Division at Argonne.

In another PME lab, Andrew Cleland, John A. MacLean Sr. Professor of Molecular Engineering Innovation and Enterprise, is also working on quantum communications. He recently sent entangled qubit states through a communication cable by creating an experimental set-up with three superconducting qubits in each of two nodes. The fragile nature of quantum states makes this process quite challenging.

He and his lab partners connected one qubit in each node to the cable—a one-meter-long superconducting cable—and then sent quantum states, in the form of microwave photons, through the cable with minimal loss of information.

The ability to remotely entangle qubits in different modules, or nodes, is a significant advance because in the future, quantum computers will likely be built from modules where families of entangled qubits conduct a computation. These computers could ultimately be built from many such networked modules, similar to the way in which today's supercomputers conduct parallel computing on many central processing units connected to one another.

"These modules will need to send complex quantum states to each other, and this is a big step toward that," Cleland said.

Prof. David Awschalom

/ More sensitive sensors

PME quantum scientists have an interest in creating more sensitive sensors that could have life-saving applications.

For instance, scientists have long wanted to be able to forecast earthquakes. Thus far, no one has figured out how to detect when Earth's tectonic plates might rub together, get stuck, and build up pressure that results in an earthquake.

Sensors that employ quantum entanglement, in which two particles such as electrons are so intimately associated that they affect each another even when they're separated by large distances, might have the sensitivity to feel early tremors deep beneath the earth.

As a first step, scientists need to figure out how to harness quantum mechanics to enhance sensors in a cost-effective, practical way.

Prof. Aashish Clerk's lab recently calculated a method that increases a quantum sensor's sensitivity exponentially without using extra energy and without increasing the inevitable noise from quantum fluctuations.

"This could even help improve classical sensors," said Clerk. "It's a way to build more efficient, powerful sensors for all kinds of applications."

/ Faster computers

Asst. Prof. Tian Zhong is exploring whether rare-earth elements that include lanthanum, a metal used in lighting for television and film, might make a good qubit. The rare-earth elements that he is working with have demonstrated superb quantum coherence properties desirable for quantum technology, and the fact that they are already mass produced for lighting—as well as in other electronics such as TV displays, laser pointers, and mobile phones—makes them an attractive choice.

Zhong hopes that rare-earth elements, already common in electronics, will become the silicon of quantum services. Silicon, a chemical material that conducts electricity, is used to power all kinds of digital devices.

"We would like to reinvent this 'common' material into something new that can decisively empower future quantum technologies," he said, "just as silicon material transformed digital electronics 50 years ago."

Awschalom, his students, and collaborators at Northwestern University developed a new method of making qubits by encoding quantum information into individual molecules. Quantum systems made from this kind of chemical qubit could be incredibly tunable, scalable, and easier to engineer at the atomic scale. In addition, his group created and controlled single electron and nuclear quantum states in commercial semiconductors, which can be used as qubits and integrated with quantum-based communications.

"Controlling qubits has the potential to bring us closer to practical quantum computers," Awschalom said. "That control is the foundation of our ability to develop high-fidelity quantum logic."

/ Training future quantum workers

A key tenet for a quantum future will be to have enough people trained to work in the industry. UChicago and PME have started a number of new programs to do just that.

The Chicago Quantum Exchange, for instance, launched a certificate program in Quantum Engineering and Technology for career scientists and engineers seeking a deeper understanding of the basics of quantum information science and its applications.

PME is also involved in two NSF-funded programs. The first—the Quantum Information Science and Engineering Network (QISE-NET)—offers graduate students the opportunity to take on a pressing research question by giving them funding and grouping them with both an academic adviser and one from a leading technology company or national laboratory. QISE-NET has now supported more than 80 students, and has graduated some of its first awardees. The second—QuSTEAM: Convergent Undergraduate Education in Quantum Science, Technology, Engineering, Arts and Mathematics—will reshape how quantum information science and technology is taught to undergraduates.

"When you ask companies around the country what is their primary concern, is it engineering quantum information technology? Is it identifying potential applications?" said Awschalom. "The number one concern is creating a trained workforce. Industries in the US expect to hire over a million people in quantum engineering."

Meeting that demand won't be easy, but PME plans to be at the forefront, giving its students the knowledge and skills to lead the world in the upcoming quantum revolution.

2013 David Awschalom, Giulia Galli
2014 Andrew Cleland
2015 Supratik Guha
2016 Jiwoong Park
2017 Aashish Clerk, Alex High
2018 Tian Zhong
2019 Hannes Bernien, Liang Jiang, Peter Maurer, David Schuster, Shuolong Yang
2020 Laura Gagliardi, Jonathan Simon
2021 Paul Alivisatos

QUANTUM ENGINEERING FACULTY

CREATING A HUB FOR CUTTING-EDGE QUANTUM SCIENCE

When the Chicago Quantum Exchange (CQE) opened its doors at UChicago's Pritzker School of Molecular Engineering (PME) in June 2017, it was the beginning of a bold effort to make the Chicago region a leader in the development of quantum technology.

David Awschalom, UChicago's Liew Family Professor in Molecular Engineering, Argonne senior scientist and director of the CQE, first proposed the idea of creating an intellectual hub for quantum research soon after he joined the UChicago faculty in 2013.

The Chicago Quantum Exchange is anchored by the University of Chicago, Argonne National Laboratory, Fermi National Accelerator Laboratory, the University of Illinois Urbana-Champaign, the University of Wisconsin-Madison, Northwestern University, as well as partners across the globe. It also includes more than 20 industry partners.

The CQE brings together a community of researchers who share the common goal of developing radically new types of quantum devices, materials, and computing techniques. The hub also strives to educate a new workforce of scientists and engineers to build the new quantum economy.

Through workshops and meetings, the CQE facilitates collaboration and knowledge-sharing among its community of academic, national lab, and industry researchers, building a network of quantum innovation across the Chicagoland area and beyond. It also hosts the annual Chicago Quantum Summit, where speakers from academia, industry, and government come together to discuss the future of the field.

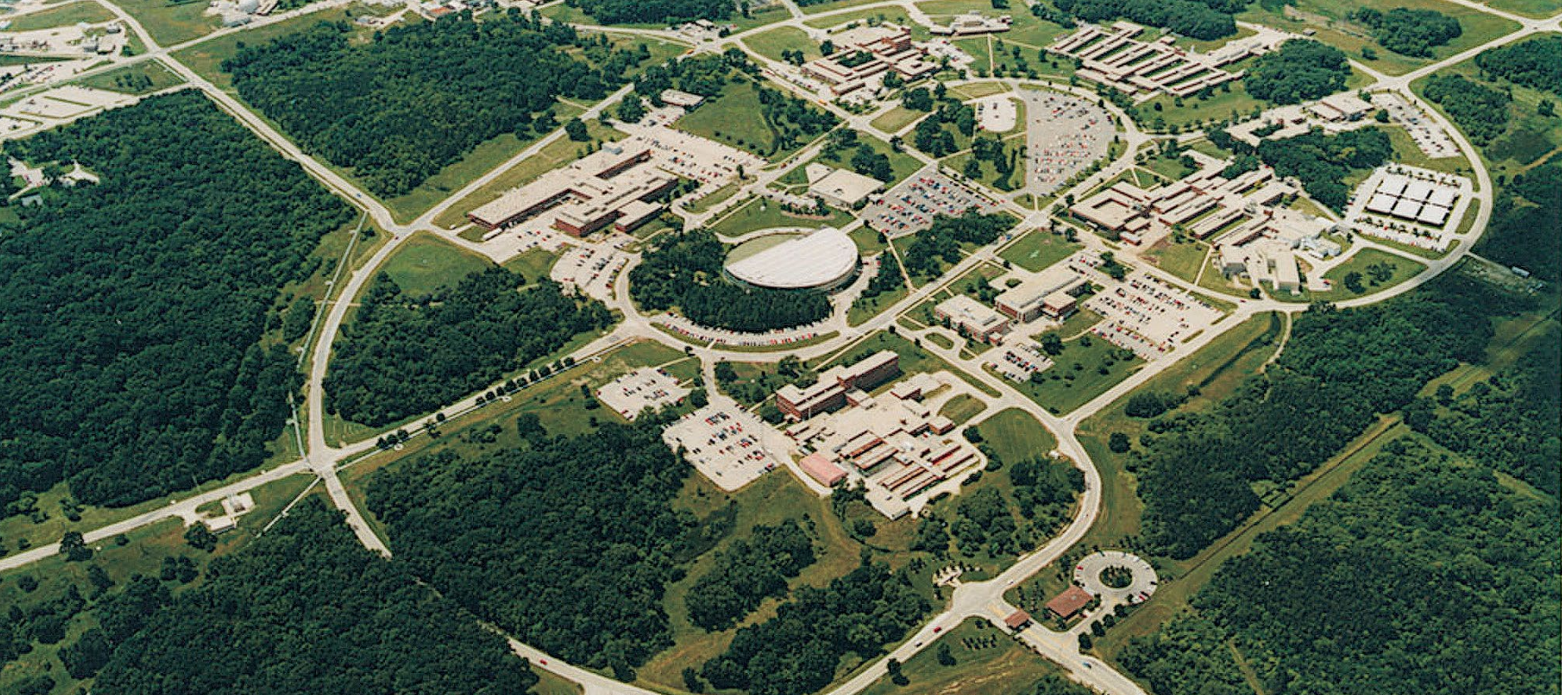
/ Future quantum workforce

As part of its effort to create a new quantum workforce, the CQE manages UChicago's role in the Quantum Information Science and Engineering Network (QISE-NET) program, which funds graduate students in quantum science from across the United States to do collaborative research with industry or national lab scientists as part of their PhD work.

Other educational initiatives include a Certificate in Quantum Science and Engineering specifically for classically trained scientists and engineers who are currently in the workforce, and a program called TeachQuantum that embeds local high school teachers in research labs to help them learn quantum-focused concepts and build curricula to use in their classrooms.

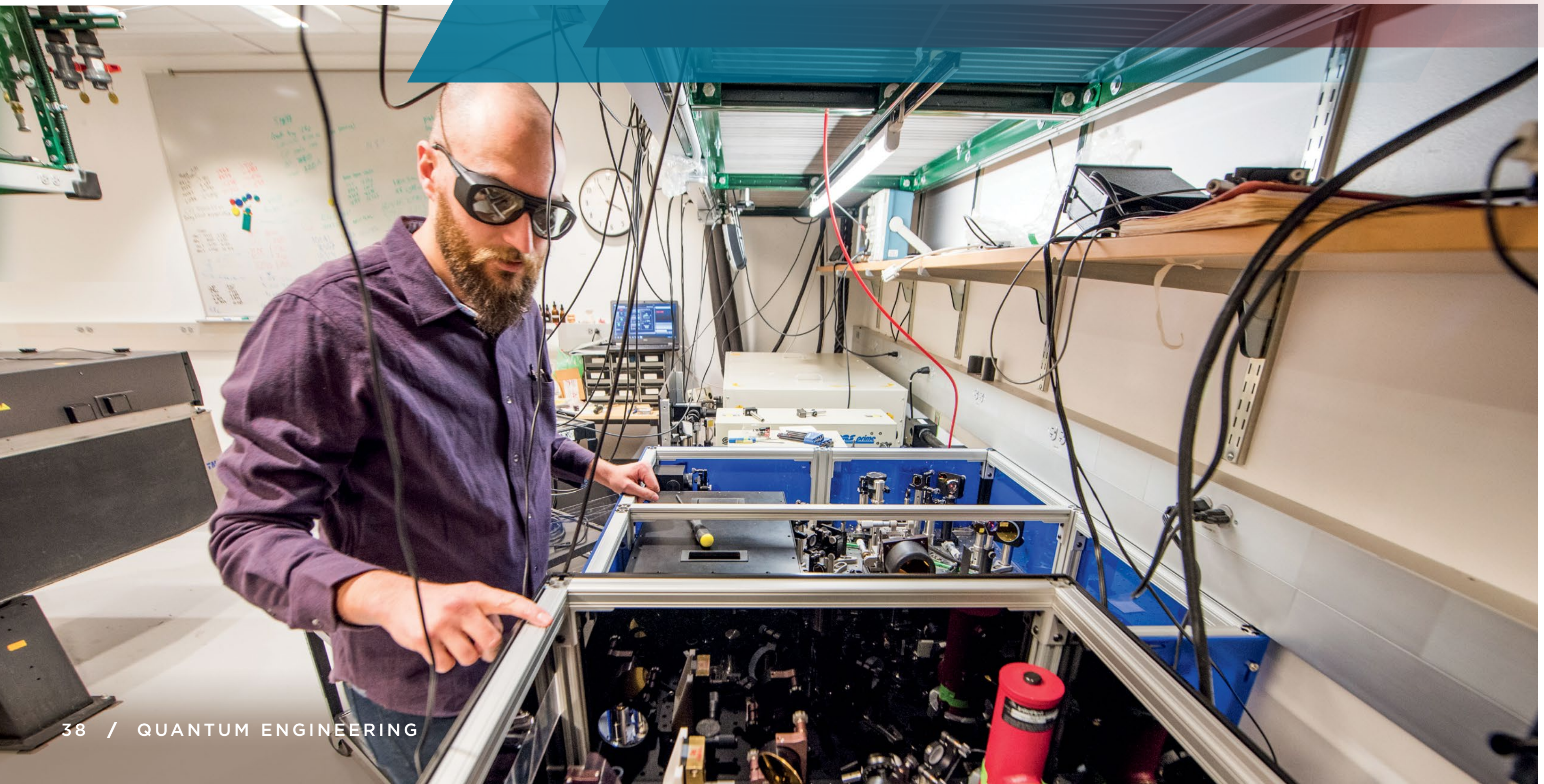
As part of the CQE's goal to create a local quantum economy, the center along with UChicago's Polsky Center for Entrepreneurship and Education helped launch Duality, the first U.S. startup accelerator focused on quantum technologies. Founding partners include Argonne, UIUC, and P33, a new non-profit focused on making Chicago a tech leader.

"Developing a new technology at nature's smallest scales requires strong partnerships with complementary expertise and significant resources," said Awschalom. "CQE brings together leading experts, facilities and industries from around the world to revolutionize the field of quantum science and engineering."



CHICAGO LEADS QUANTUM REVOLUTION

WITH TWO NATIONAL CENTERS



In August 2020, the federal government showed its commitment to leading the quantum frontier by establishing five National Quantum Information Science Research Centers, supported by the U.S. Department of Energy (DOE). Two of the centers are headquartered in the Chicago area—at Argonne National Laboratory and Fermi National Accelerator Laboratory—a testament to the region's status as a powerhouse in quantum science.

Located in the Chicago suburbs, both laboratories are affiliated with the University of Chicago and are founding members of the Chicago Quantum Exchange (CQE), which convenes partners around Chicagoland to further quantum research. The CQE is directed by Vice Dean for Research and Infrastructure and Liew Family Professor of Molecular Engineering David Awschalom.

The national centers—Q-NEXT, led by Argonne, and the Superconducting Quantum Materials and Systems Center (SQMS), led by Fermilab—bring together world-leading experts and top-tier facilities in support of the National Quantum Initiative, a coordinated federal program with a goal of accelerating quantum research and development for the nation's economic and national security. Each center will receive $115 million, distributed over five years.

/ Pioneering quantum communication and computing

Q-NEXT, directed by Awschalom, is developing the technology to reliably transmit quantum information at distances that could be as small as a computer chip or as large as the distance between Chicago and San Francisco. The center focuses on three core areas: quantum communication, sensing, and processing. As part of its mission, two Q-NEXT lead institutions, Argonne and Stanford University, are building two national foundries that will act as a "quantum factory," producing a robust supply chain of high-quality, standardized materials and devices for known and yet-to-be-discovered quantum applications. The center will also establish the first National Quantum Devices Database to promote the industrial development of next-generation quantum devices. Workforce development is a vital part of the Q-NEXT program, and through its partnerships, Q-NEXT provides future scientists and engineers with practical experience on quantum information problems, building a quantum-smart workforce to ensure US leadership in this rapidly advancing field.

SQMS research focuses on one of the most critical problems in quantum information science: increasing the length of time that a qubit, the basic element of a quantum computer, can hold information, also called quantum coherence. The center aims to build and deploy a beyond-state-of-the-art quantum computer based on superconducting technologies as well as new quantum sensors, which could lead to the discovery of the nature of dark matter and other elusive subatomic particles. SQMS researchers also plan to build the largest dilution refrigerator in the world to host both 2-D and 3-D quantum processors and a large number of qubits.

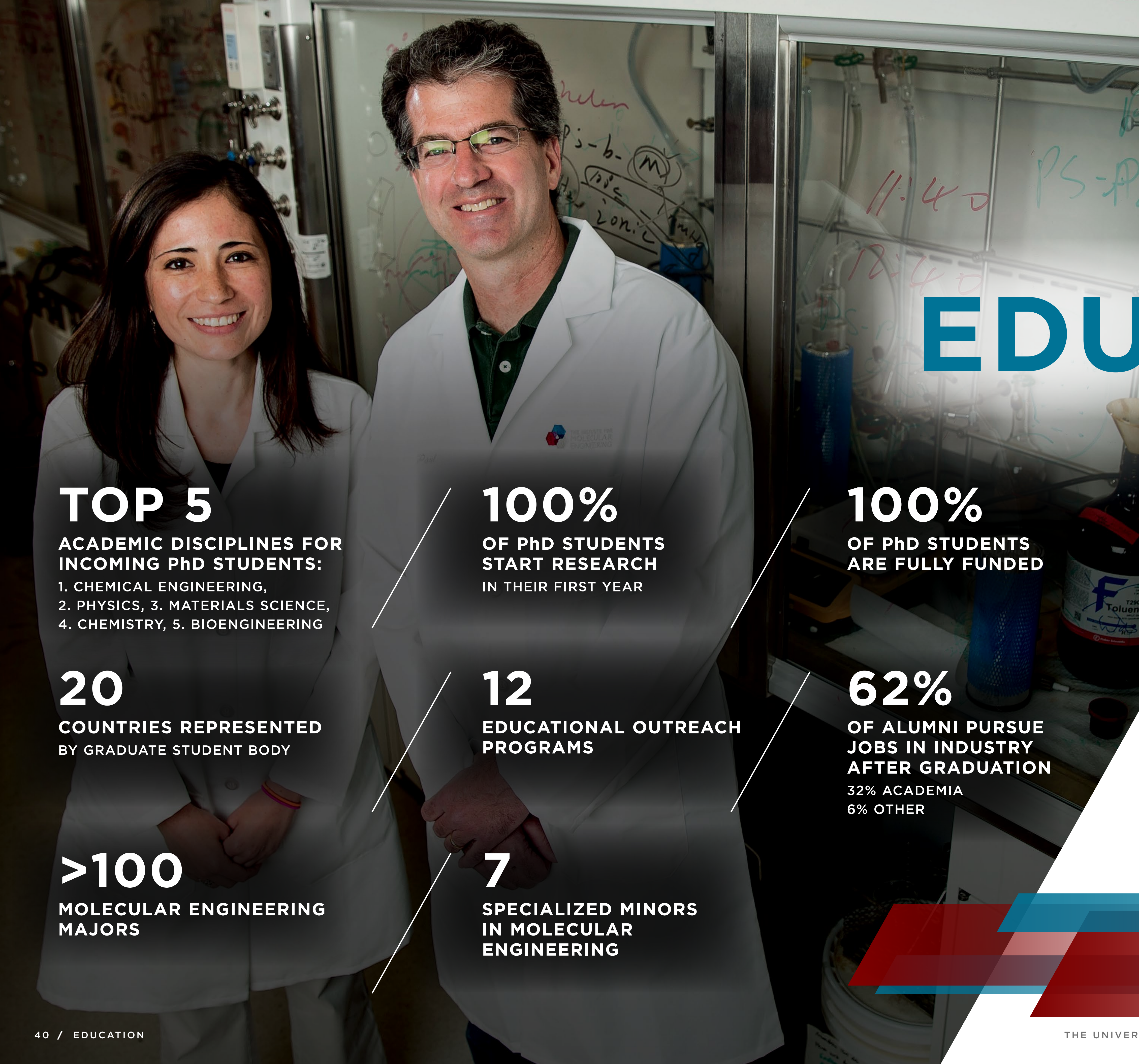
/ The National QIS Research Centers: The next Bell Labs?

The new quantum centers bring together experts from national labs, universities, and industry, fostering a convergence of research discipline and expertise, something that Awschalom sees as critical for quantum science to evolve. He points to the birth of the transistor—a device that runs many of today's electronics—at Bell Laboratories in the late 1940s as an example of the scientific breakthroughs that are ignited when a diverse group of scientists working with top-notch facilities comes together to do research. Collaboration with national labs and partner institutions can have a similar impact, he says, accelerating quantum innovation and discovery.

"A remarkable amount of fundamental science takes place in this type of unusual, multidisciplinary environment," said Awschalom, speaking of Bell Labs, which was run by AT&T and Western Electric and whose scientists won nine Nobel prizes. "It's not that the scientists in such places are different. It's that the mode of working is highly cooperative and drives creativity."

With two of the five U.S. DOE quantum centers based in Chicagoland, that same collaborative, innovative science is happening here, bringing PME faculty, their colleagues at other institutions, and Argonne and Fermilab experts together to advance quantum science.

Says Awschalom, "We have the opportunity to become the next Bell Labs."



Paulina Rincon Delgadillo, PhD'14, PME's first graduate, and Vice Dean for Education and Outreach Paul Nealey.

EDUCATION

TOP 5
ACADEMIC DISCIPLINES FOR INCOMING PhD STUDENTS:
1. CHEMICAL ENGINEERING, 2. PHYSICS, 3. MATERIALS SCIENCE, 4. CHEMISTRY, 5. BIOENGINEERING

100%
OF PhD STUDENTS START RESEARCH
IN THEIR FIRST YEAR

100%
OF PhD STUDENTS ARE FULLY FUNDED

20
COUNTRIES REPRESENTED
BY GRADUATE STUDENT BODY

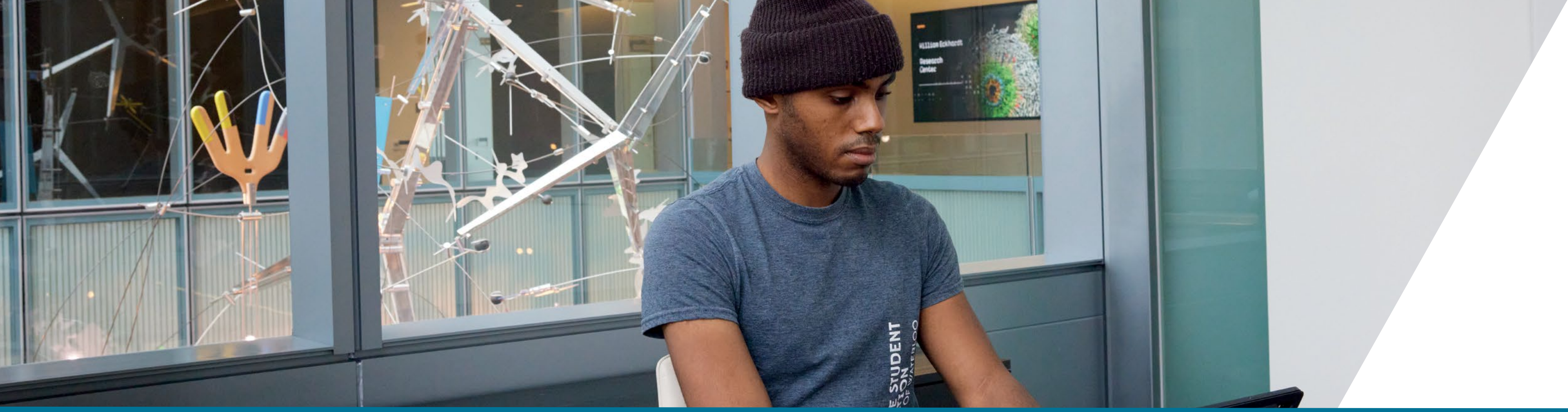
12
EDUCATIONAL OUTREACH PROGRAMS

62%
OF ALUMNI PURSUE JOBS IN INDUSTRY AFTER GRADUATION
32% ACADEMIA
6% OTHER

>100
MOLECULAR ENGINEERING MAJORS

7
SPECIALIZED MINORS IN MOLECULAR ENGINEERING

The Pritzker School of Molecular Engineering is dedicated to providing a transformative education in science and engineering. We offer master's and PhD degrees, and partner with The College at the University of Chicago on an undergraduate major and seven highly adaptable minors. We also lead multiple outreach programs to foster an ongoing relationship with the South Chicago community and to inspire the next generation of molecular engineers.



AN EDUCATION TO SOLVE GRAND CHALLENGES

Pritzker School of Molecular Engineering (PME) faculty designed a program steeped in convergent learning so students leave prepared to tackle some of the world's most pressing problems

When Prof. Paul Nealey, vice dean for education and outreach, was earning his degrees, he and nearly every other chemical engineering student took classes that kept them separated from their peers. Isolated by their coursework and learning their new discipline with rigid, singular focus—for them, there was only chemical engineering. The same was true for the students in the other engineering majors.

"That's how undergraduate and graduate STEM education, especially for disciplines like mine, was set," said Nealey, the Brady W. Dougan Professor in Molecular Engineering. "It's the same across all universities, and has been the same for 40, 50 years."

/ Curriculum for the future

But whether it's in industry or academia, modern engineers have to work hand-in-hand with disciplines outside their own—especially if they want to take on society's grand challenges. The Human Genome Project, for instance, was made up of engineers, biologists, chemists, and mathematicians.

This is why decades later Nealey and the other architects of the Pritzker Molecular Engineering curriculum designed it to be inclusive from Day One. What emerged was a groundbreaking program with a master's degree, a PhD program, and an undergraduate major offered through the College at the University of Chicago, all built to foster the level of convergent thinking that's needed to tackle everything from creating biodegradable plastics, to making the first quantum internet, to training the immune system to attack cancer cells.

> **"We've designed a program to educate students for the next 100 years ... and that means doing things differently than the last 100 years."**
>
> **Professor Paul Nealey**
> Vice Dean, Education and Outreach

"We've designed a program to educate students for the next 100 years," said Nealey, "and that means doing things differently than the last 100 years."

/ Top of their game

In 2013, shortly after Nealey and three other faculty members helped Dean Matthew Tirrell launch PME, they established a PhD program and began recruiting doctoral candidates from a variety of science and engineering fields, looking especially for those with an interest in entrepreneurial opportunities and developing technological solutions that would have a high societal impact.

Many of those early students—and those that followed—focused on one type of engineering during their undergraduate studies. When they arrived at PME, rather than building exclusively on that speciality, they now had to take classes in quantum physics, materials engineering, and immunoengineering.

"They've been at the top of their game. That's how they got into a top engineering school, and now they're in a classroom where they're starting from scratch," said Rovana Popoff, senior associate dean for education and strategy. "It says a lot about the students that we recruit that they're up for that challenge, but also that they understand, ultimately, the value of going through that experience."

/ Tackling big problems

That's certainly true for Adarsh Suresh, a doctoral student from Bangalore, India, who is researching how to use electrochemical methods to generate potable water from contaminated sources.

"I've experienced and I've witnessed water shortage, water pollution," Suresh said, "and you have to be able to use skills from physics, from chemistry, from biology, from art, from everything, in order to solve these global problems, global crises that we're facing right now. And [PME] really offered that up front."

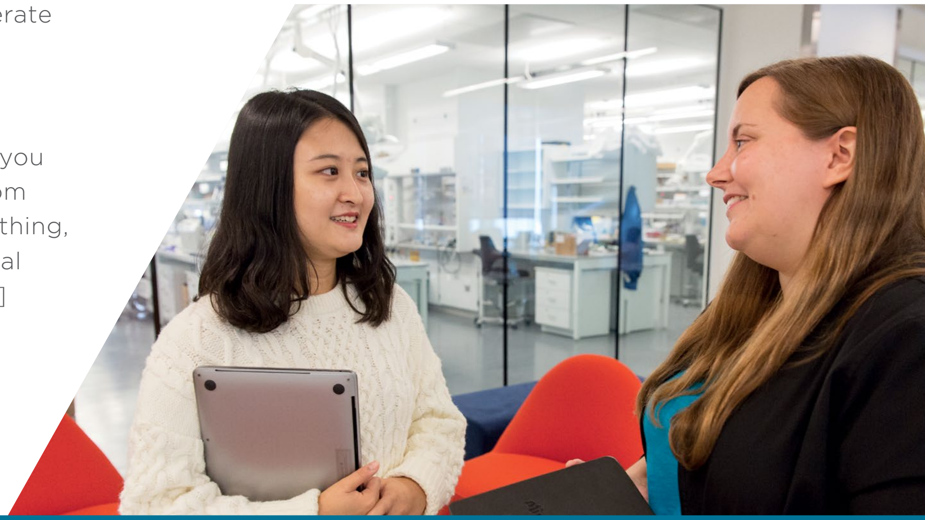
PME also gave Paulina Rincon Delgadillo, PhD'14, the opportunity to gain real-world experience while working on her doctorate. Under the tutelage of Nealey, her faculty advisor, Rincon Delgadillo spent two and a half years working at imec, a global R&D hub in Belgium for nano- and digital technologies. There, she helped implement directed self-assembly of block copolymers, a process she had studied that could ultimately be used for computer chip manufacturing.

Then, she returned to the United States to finish her degree, becoming the first graduate from PME's PhD program. Today, Rincon Delgadillo is a senior researcher at imec who studies extreme ultraviolet lithography. She never would have gotten there without PME, she said.

"Being part of PME and the University of Chicago opened up a lot of possibilities for me, in the United States and in Europe," said Rincon Delgadillo. "I was able to choose where in the world I wanted to work."

/ Tailored to their interests

In 2019, six years after creating the doctoral program, PME added another layer of graduate education, a master of science in molecular engineering (MSME). The MSME offers two tracks. One is computational materials modeling, which, in addition to materials science, offers the opportunity to learn computation methods for tackling the study of machine learning and artificial intelligence. The other is polymer science and engineering, which delves into things like nanomedicine, biosensors, and polymer physics.



Many MSME graduates will pursue careers as leaders in manufacturing, technology development, and research, but the program is also designed so students can branch out into diverse fields such as law, medicine, business administration, consulting, entrepreneurship, or policy.

"We give the MSME students the ability to tailor the curriculum to their specific background and professional goals," said Assoc. Prof. Andrew Ferguson, one of the faculty leads for the computational materials modeling track.

That has worked well for Sonia Vohra, MSME'21. She was drawn to the program after conducting undergraduate research on a small island off the northern coast of Panama. While involved in that research, she was shocked to find an abundance of trash floating in the water and washed ashore. Vohra hopes to use her polymer science and engineering education to contribute to advancements in the sustainability sector, working in industries that focus on the development of effective and environmentally friendly materials to combat various types of environmental pollution.

"I am excited to be a part of a program that looks at complex engineering problems fluidly and from the perspectives of different fields," she said, "and to work with others at the University of Chicago in our shared mission of creating meaningful, cutting-edge technology to improve the quality of life for all beings on our planet."

/ An ambitious future

Much has been accomplished since PME's founding in 2011, but the school's future plans are no less ambitious. For instance, a new $3 million NSF grant for teaching graduate students will allow faculty to integrate the molecular engineering curriculum with artificial intelligence and machine-learning training to give master's and doctoral students greater computational data skills.

In addition, a recently started program called the Quantum Information Science and Engineering Network offers select graduate students funding and a rare opportunity to receive mentorship from both a PME faculty member and an industry or a national laboratory scientist.

And a new program called The Committee on Immunology gives PhD students the chance to take a truly convergent approach to their education with interaction in four different areas: biomedical science, molecular science, molecular bioscience, and neuroscience.

Lastly, senior faculty are discussing adding several new themes to the mix and are also evaluating junior faculty who might one day carry PME's leadership torch. Nealey and his colleagues also want to continue to grow the molecular engineering student numbers at every level: undergraduate, master's, and PhD, with hopes of doubling the program's size in the next decade.

"The plan," said Nealey, "is to establish an identity as one of the premier engineering programs in the country."

EDUCATION MILESTONES

- **2013** PhD program and molecular engineering minor established
- **2014** First PhD in molecular engineering awarded
- **2015** Molecular engineering major established
- **2018** First class of undergraduate molecular engineering majors graduate
- **2019** Master's program launches

A LEGACY OF GIVING

Bernard J. DelGiorno, AB'54, AB'55, MBA'55, has been a lifelong supporter of the University of Chicago, and when he first learned about its emerging program in applied science—the Pritzker School of Molecular Engineering (PME)—he knew he wanted to lend a hand.

"Right away, I understood this new school was going to accomplish remarkable things," DelGiorno said. "The scope of their work, their research—it's a pursuit I fully support, and so I wanted to give something as my little way of saying, 'do it.'"

That "little way" was a $1 million donation, given to the school in 2016 as an unrestricted fund, a method of support that allows Pritzker Molecular Engineering leadership to direct the money where it's needed the most.

With his gift, DelGiorno continued his legacy of giving to UChicago, which has contributed to athletic facilities, student housing, the creative and performing arts, the Odyssey Scholarship program, and the 2006 renovation of Stagg Field.

DelGiorno, a former varsity gymnast at UChicago and member of Phi Gamma Delta (FIJI), is currently the first vice president of wealth management at UBS Financial Services and a resident of Hyde Park. To him, investment in the school is a way of both honoring and growing the institution that showed him much in his early life.

"I came to the school as a recipient of the Adams History Scholarship and, from that moment on, my respect and appreciation for the University of Chicago has only grown," DelGiorno said. "The support I received and the ideas I was exposed to because of that scholarship were hugely impactful. For me, giving to the University, especially to student aid programs, is a way of continuing that tradition. It's a way of providing future students with the same opportunity that was afforded to me."

DelGiorno said he looks forward to seeing what PME will accomplish in the years ahead and how the University of Chicago will grow in turn.

THE VOICE OF EXPERIENCE: INDUSTRY SEMINARS AT PME

The Industry Seminar Series, which launched in 2020, gives business leaders an opportunity to visit the Pritzker School of Molecular Engineering (PME) and discuss the trends, challenges, and opportunities that exist in their field. Held every quarter, the series also allows industry partners a chance to interact with Pritzker Molecular Engineering students and build a relationship with the school itself. For the students, it's an opportunity to learn about potential career paths and how to better navigate the private sector after graduation.

"These talks are a great way to give students new perspectives on the world outside academic research—not just the work, but also the atmosphere and culture," said Felix Lu, director of corporate engagement and organizer of the series. "Students get to learn about new fields, and they also hear stories about how careers can shift in unexpected ways and how scientists and engineers have adapted to changing technologies. Each one has been an enlightening experience."

Since its inception, the series has covered a broad range of topics including the international space station, microbiology, supercomputers, distillation, the space economy, and finance. Previous speakers have included representatives from Nvidia, Eli Lilly, Avery Dennison, SpaceMicro, and Merck KGaA.

Speakers describe their career paths, from getting advanced degrees in science and engineering disciplines to the twists and turns that led them to their current job, which could be technology recruiting, entrepreneurship, or performing research and development.

At the very first industry speakers event, held in February 2020, David Hurst, founder and CEO of Orbital Transports, told the audience of students, postdocs, and faculty about exciting new prospects for materials science and commercial applications in space.

Hurst discussed prospects of commercial endeavors in space, including mining near-earth asteroids, the logistics and methods of launching small satellites, and the current projects his company is undertaking.

"The talk was a great fit for PME, since the school's research is all about developing new technology to solve problems or achieve things we couldn't before." said graduate student Paul Jerger. "The event gave me the opportunity to hear from an industry professional with a lot of experience, and it was informative to hear David speak about starting and operating companies."

Looking ahead, PME plans to grow the series by offering more lectures from an ever-expanding list of industry partners.

"Understanding the business environment and forging these connections with industry partners is an essential element of PME's mission," Lu said. "It's from these partnerships and from the conversations fostered by the lecture series that new technologies and innovations emerge."

PLANTING THE SEEDS OF PARTNERSHIP: HOW ONE 3M INTERNSHIP LED TO A GROWING RELATIONSHIP

One of the chief ways Pritzker School of Molecular Engineering (PME) students engage with corporate partners is through industry internships. These present an opportunity for students to gain a broader understanding of the private sector—the demands of research in the commercial space—while also demonstrating to partners the value that Pritzker Molecular Engineering graduates can provide for their company.

Lu Li, PhD'19, participated in 3M's research and development summer internship during her fourth year. 3M, headquartered in St. Paul, Minnesota, makes consumer, commercial, healthcare, and government products. According to Li, the experience was instrumental in growing her understanding of and appreciation for research outside the academic realm. It was one thing, she realized, to pursue a topic at PME, where curiosity alone could propel a project forward, but another thing entirely to pursue one in the business world where the supply chain and market demand played a major role.

To Li, these challenges were like exciting new pieces of a puzzle, and to help her solve it, she collaborated with teams in marketing and finance, who provided wholly new insights into the process. It was a unique experience, but one that Li felt prepared for because of her time at PME.

"PME is an atypical program in a lot of ways," explained Li. "As a PhD student, I participated in the Innovation and Commercialization Fellowship program, which was run by the Booth School of Business and PME. In that program, we helped scientists with startup work. We did preliminary market analyses, and we analyzed startup IPs to assess their potential for going to market. That experience helped prepare me for working in industry, and it's not something many PhD programs have."

Li interned at 3M's Medical Solutions Division where she stood out as especially driven and adaptable, according Corinne Lipscomb, technical manager and chief product owner of materials informatics at 3M. In fact, it was thanks in part to Li's performance that 3M and PME's partnership has grown to what it is today.

"As a polymer chemist by education, I had been watching PME assemble an impressive list of faculty from around the country," Lipscomb said. "When internal discussions started to happen about building up our relationship with PME, we knew the students were high quality because of Lu.

"Today, 3M has a number of valuable connections with PME, one being the recruiting pipeline to bring in exceptional talent. To date, the Corporate Research Materials Lab has hired three PME students, and this summer we are working with a graduate intern from Assoc. Prof. Andrew Ferguson's group."

Li's internship concluded in 2018, and thanks to her work during that time, she was hired in 2019 as a senior research scientist at 3M's central lab in Minneapolis, where she continues to solve new puzzles every day.

LIBERAL ARTS MEETS ENGINEERING

Paul Nealey, vice dean for education and outreach, and other early Pritzker School of Molecular Engineering (PME) faculty knew they would need to conceive of and implement their vision for educating undergraduate engineering students within the College of the University of Chicago's renowned liberal arts framework.

For instance, all UChicago undergraduate students complete core curriculum studies—math, science, humanities, and social science—in addition to their major requirements, usually in their first two years of study.

That meant Nealey, also the Brady W. Dougan Professor of Molecular Engineering, and his colleagues worked meticulously to refine the major's requirements to focus on molecular engineering's most vital concepts, aligning them with existing and new elements of the core curriculum.

In addition, they advocated changing the timing of core classes—first-year students now routinely take math, chemistry, and physics their first year, so undergrads can access opportunities to take advanced molecular engineering coursework in subsequent years—and to impart flexibility into the curriculum so students can individualize their programs.

Students say they appreciate the streamlined major, which was introduced in 2015, because they can easily combine it with other academic interests as a double major—something that would be much harder to do at a traditional engineering school.

For instance, Hope Lee, SB'20, double-majored in molecular engineering and physics and is now a PhD student in applied physics at Stanford University. And even though Brian Schwartz, SB'18, did not double major, he tailored his UChicago experience by working in the lab of Juan de Pablo, Liew Family Professor of Molecular Engineering, for several years conducting research on synthetic nanocomposites, and he also got involved in UChicago's Institute of Politics.

"I wanted to understand the role of politics and policy in science and technology," he said, "and getting to have those conversations through the institute helped bridge what I was doing in the lab with real-world implications of technology."

/ Minors provide intensive focus

But what about undergraduates who want to take a deeper dive into a particular aspect of molecular engineering? The answer was the creation of seven minors in 2019 that were designed to be built on top of the molecular engineering major. The minors offer advanced coursework to prepare students to work at the forefront of fields such as immunoengineering, materials engineering, and quantum computing.

One minor, for instance, would be ideal for students who want to focus on using powerful computational methods to design sustainable materials for solar cells or electric car batteries. Those students would pursue the SB in molecular engineering/chemical engineering track, then complete the minor in computational molecular engineering.

> **PME faculty worked meticulously to refine the major's requirements to focus on molecular engineering's most vital concepts.**

This minor gives students exposure to machine learning, which helps researchers sift through huge data files, and to molecular simulation, which helps illuminate the physical properties of materials from first principles. Nealey said both of these skills would better prepare students to study chemistry or chemical engineering in graduate school than if they had just majored in one or the other field.

Another minor could be pursued by students who want to specialize in cancer research. Rather than completing a degree in bioengineering in a more traditional curriculum emphasizing breadth, a molecular engineering student would complete the bioengineering major as a foundation and then complete focused coursework composed of advanced senior undergraduate and graduate level courses in the immunoengineering minor. Such a student, says Nealey, "would hold a competitive advantage in entering the workforce in a highly technical role in cancer research, or going on to graduate or medical school."

Whatever path molecular engineering undergraduates take, many cite the program's design, which allowed them to combine cutting-edge engineering with other subjects, as a huge strength as they head into future endeavors.

"I think the molecular engineering program equipped me with the fundamentals that allow me to absorb and read up on any kind of subfield of knowledge I need in order to achieve a final research goal," said Lee. "One concrete example is having the required chemistry sequence as part of the molecular engineering major—that's not something that was required for my other major. But now in my applied physics research at Stanford, I find myself returning to those chemical concepts in a way that I never would have anticipated. It's really an advantage."

/ Attracting top-notch undergrads

Looking ahead, there are a range of new programs designed to attract more undergrads to UChicago's many molecular engineering offerings, including:

- The Engineering Fellows Program, a three-year, selective program that provides specialized advising and programming for students of all majors passionate about engineering careers.
- The Prototype for Success Career Program, which will support a cohort of students with dedicated programming, funded summer research and internships, and a capstone project focused on innovation and entrepreneurship in "deep tech" that includes agriculture, biotechnology, engineering, green energy, and healthcare.
- The Pritzker Scholar, an award guaranteeing internships and specialized programming to students studying molecular engineering. Nealey compares the award to the Rensselaer Medal, which has been handed out for more than 100 years to recognize high-achieving high school students and encourages the study of science, engineering, and technology.

These initiatives and others are designed to attract the best undergrads to come to UChicago and potentially major in molecular engineering.

"The College is doing some amazing things toward building excitement about coming here to study engineering," said Nealey. "I think it's going to have a huge impact."

> **"Minors offer advanced coursework to prepare students to work at the cutting edge of fields such as immunoengineering, materials engineering, and quantum computing."**

GIVING TO A VALUED MENTOR

In the fall of 2014, David Farr, SB'19, then a high school senior, had just finished touring the University of Chicago when he had a realization: "This is where I'm going to college for the next four years."

Farr's requirements for a school were very specific: it needed to have a top-tier pre-med program and an established swim team. UChicago fit that bill perfectly. It also checked off his final requirement—an innovative engineering program. During his tour, Farr learned about the Pritzker School of Molecular Engineering (PME), known at the time as the Institute of Molecular Engineering (IME), and their innovative work in immunoengineering struck a chord.

"It was in that moment when everything came together better than I ever expected," Farr said. "UChicago not only had a strong reputation, but they also had this novel molecular engineering program that was applying engineering principles to tackle the most challenging problems in immuno-oncology, amongst many other fields. I knew pretty quickly this was the perfect place and major for me."

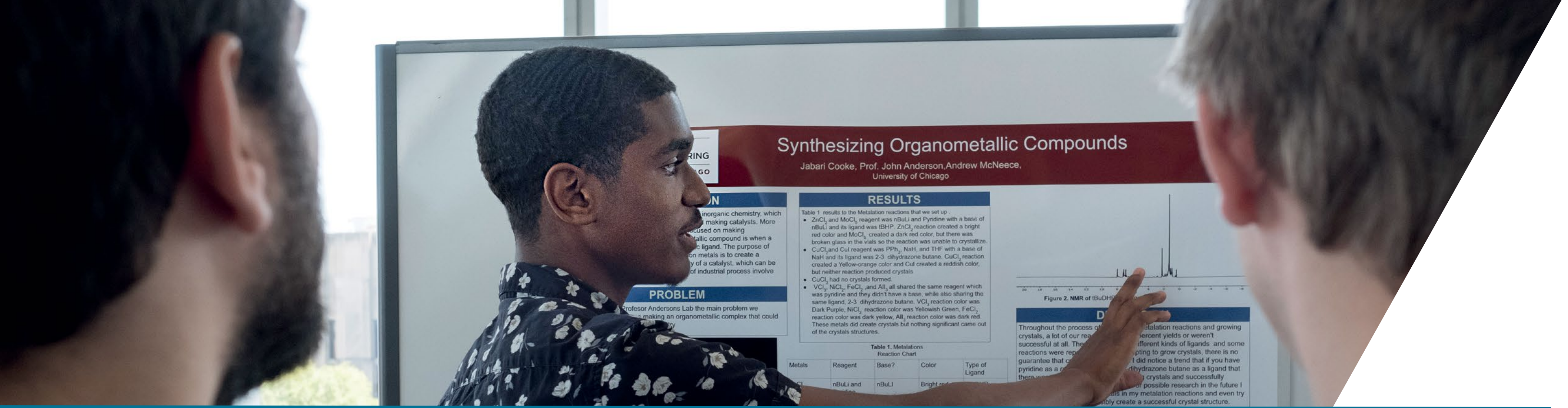
After enrolling, Farr immersed himself in Pritzker Molecular Engineering, specifically immunoengineering. What he learned in that first year made such an impact that he asked Melody Swartz, the William B. Ogden Professor of Molecular Engineering and co-director of the Chicago Immunoengineering Innovation Center, for the opportunity to work in her lab over the summer. "Absolutely," she said.

That summer proved to be so transformative that Farr continued to work in Swartz's lab for the remainder of his undergraduate career. In 2019, he graduated from the University of Chicago as a pre-med candidate with a BS in molecular engineering with a specialty in biological, chemical, and soft materials.

For Farr's parents—Lisa and Scott Farr—the skills and education their son received at UChicago, specifically under Swartz's guidance, was of such a high value that they chose to directly to her lab.

"We could have donated anywhere at the University," Lisa Farr said. "But it was Melody, her mentorship to David, that really inspired us to show our appreciation."

Since graduating, David Farr has taken a position as a technical project manager at a cell- and gene-therapy biotech startup in the Bay Area, where he continues to explore the intersection of immuno-oncology and molecular engineering, aiding in the fight to cure cancer.



COMMUNITY COMMITMENT

When Pritzker School of Molecular Engineering (PME) founders envisioned the future, they pictured one with robust sustainable energy options, a clean global water supply, advanced communications networks, and wholly new strategies for treating disease and cancer. They also envisioned a future that was equitable.

They believed that in order to create a better world, institutions like Pritzker Molecular Engineering had to foster trusting, long-term relationships with the local community. Gone was the idea of scientists as mysterious toilers and cryptic knowledge keepers; instead, scientists would become engaged mentors to the public—especially to the public around the University of Chicago where funding for science education has long been scarce.

/ Two-way street

“We are creating a culture where engaging the community is a central priority,” said Laura Rico-Beck, assistant dean of education and outreach, who nurtures those community connections. “That goes directly to address the inequities in science.”

Just as faculty and students offer science learning opportunities to the community, the community offers them a variety of opportunities as well. For instance, faculty and students learn how to speak about their work in ways that are relevant to a wide range of audiences. They also improve their ability to work collaboratively with community partners, and they develop community-based scholarship competencies. These interactions, in turn, often impact their approach to science inquiry and how they think about their own research.

“It goes both ways,” said Rico-Beck. “That is, we can communicate and engage the community with the science content. And then we can also learn from the community about what’s important, what’s needed, and how the science and the research that’s happening at PME can contribute to and become part of their lives.”

/ Clear communicators

All PME graduate students have the opportunity to train in intensive workshops to better understand how to convey their work to a broad audience and how to engage individuals with science and engineering.

“Being able to explain your research, not just to other scientists, but to policy makers or investors, is critical,” said Rovana Popoff, senior associate dean for education and strategy.

The graduate students who decide to take part in the communication workshops then engage in the outreach programs, which include teaching Junior Science Cafes for middle schoolers, staging a molecular engineering fair for the nearby neighborhoods, mentoring high school and community college students through numerous programs, and assisting with TeachQuantum, a new faculty-led program that the helps local high school science teachers develop quantum lessons for the classroom. A select group of these graduate students, called Science Communication Fellows, take part in more advanced outreach activities and also lead some of the trainings themselves.

“I want students to come away with a notion of what a scientist can look like, and that they are real people and can come from lots of different backgrounds,” said Taylor Gray, PME doctoral student and Science Communication Fellow. “I also want them to see that science can be really fun, even though it can be challenging at times.”

/ A lasting commitment

The common thread between all these programs is their focus on long-term impact. Popoff and Rico-Beck purposefully design the outreach programs to engage the community and to be interconnected and cohesive. This means that there are a variety of ways for community members to engage, and that those who get excited about the science and engineering they experience can connect to more resources, new experiences, and opportunities to pursue longer-term goals like a four-year college program and a STEM-related career.

That was the case for Mia Grahn, who took part in a PME-related research internship in 2019 when she was a rising senior at Chicago’s William Jones College Preparatory High School. Now a junior at Johns Hopkins University, Grahn said she learned something invaluable during her internship.

“I realized that I could actually learn by engaging in discussions with others,” she said. “And that my questions allowed them to think differently, and [in turn] they reacted to me in ways that allowed me to think differently.”

Making those kinds of intellectual leaps is what PME’s outreach is all about.

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