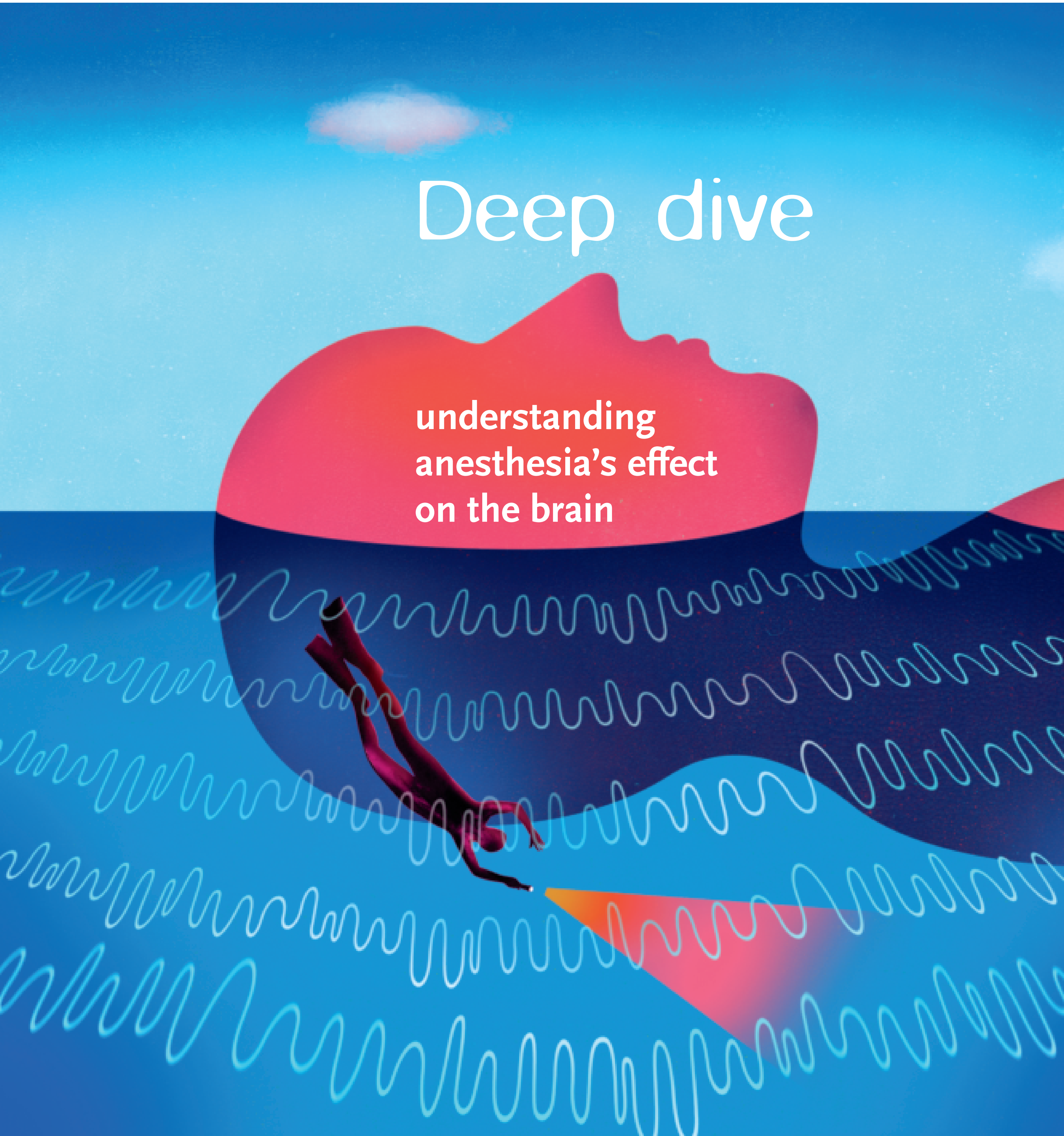
MIT

Science AT MIT

Winter 2022 **Published twice yearly**



Deep dive

understanding anesthesia's effect on the brain

Science AT MIT

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SCHOOL OF SCIENCE
Massachusetts Institute of Technology

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Letter from the Dean

My fellow alumni and friends,

We have now passed the winter solstice and light is once again returning to Cambridge. Though we are still firmly entrenched in New England winter, knowing the days are growing longer is a boon. No matter the wintry weather, research at the School of Science continues unabated.

In this issue, Dr. Emery Brown, a practicing anesthesiologist at Massachusetts General Hospital (MGH) and a professor in the Department of Brain and Cognitive Sciences, walks us through what was, up until the last decade, the modern mystery of anesthesia's effect on the brain. MIT, in collaboration with MGH, is actively fundraising around an Anesthesiology Initiative that will support Emery's neuroscience approach to studying how the state of general anesthesia is induced and maintained. In our cover article, you can read more about his next steps in a research program centered around the tools of modern neuroscience.

Alumnus George Elbaum was awestruck by Brown's recounting of the dearth of research on anesthesia in a clinical setting; so much so that he committed ongoing support for Brown's research — even though brain and cognitive sciences is a far cry from Elbaum's formal MIT degrees: a bachelor's in 1959 and a master's in 1963, both in aeronautics and astronautics — and a master's in 1963 and a PhD in 1967, both in nuclear engineering.

Support from insatiably curious alumni and friends is one way in which we keep our research enterprise sharp. Over the summer, Professor Emeritus Paul Schimmel and his wife Cleo, made a $50 million pledge to the Department of Biology to support graduate students and research in the life sciences at MIT. Twenty-five million dollars was given in an outright gift and $25 million was made available to match new gifts to this fund. One of the first people to take advantage of this opportunity was our very own Institute Professor Phillip Sharp.

Alumnus John Jarve '78, SM '79 also recently lent his support to the school in the form of research seed funding grants. Over the last three years, Jarve has supported more than 20 proposals across the school's multitude of research disciplines and has spurred the Dean's Office to fund close to 50 other projects. You can read more about of these burgeoning research programs beginning on page 19.

Additional seed funding was earmarked specifically for the Department of Mathematics thanks to a donation from Stephen Berenson '82 (see page 14). This donation will help support nascent faculty and student research projects, as well as ideas not easily funded through traditional channels. Berenson called it "exploration capital" and we know just how much our community can accomplish when given the resources to truly explore all avenues.

For example, on page 16, you can learn about the achievements of our students in the Program for Research in Mathematics, Engineering and Science for High School Students (PRIMES). The research productivity of these students is inspiring — with close to 300 published papers, 20 percent of which have been in academic journals and conference proceedings. And many of these students come back to MIT to begin their studies in earnest as first-year students. Kudos go to PRIMES chief advisor Professor Pavel Etingof and program director Slava Gerovitch, as well as the program's alumni who continue to help the program succeed.

In recent research news, you can read about MIT's mission to Jupiter's asteroid belt. The Lucy spacecraft will swing twice around the Earth before heading out to the Trojan asteroids on one side of Jupiter and then back by Earth again for another slingshot to the other side of the solar system's largest planet to investigate other asteroids — all over 12 years and nearly 4 billion miles. Mission co-investigator Richard Binzel, professor of planetary sciences in EAPS, outlines the research goals for the Lucy spacecraft on page 22.

On page 10, you can read about new faculty member Arlene Fiore, our first holder of the Peter H. Stone and Paola Malanotte Stone professorship in EAPS, who seeks to understand how pollutants influence atmospheric chemistry, the climate system, and air pollution on local and global scales. A more detailed look at her research using satellite data to track pollutants can be found on MIT News.

Finally, on page 12 you can read a profile of Robert Gilliard, a self-described "exploratory chemist" and Martin Luther King Jr. Scholar in the Department of Chemistry, who is working with Professor Christopher Cummins to create novel molecular structures with potential applications in optics and catalysis.

These stories and others continue to inspire me through the seasons and fill me with hope for the future of science at MIT and beyond. I hope they do the same for you.

With my very best wishes,

Dean Nergis Mavalvala PhD '97

Improving anesthesia with neuroscience

3 Questions for Dr. Emery N. Brown

David Orenstein | The Picower Institute for Learning and Memory

Emery N. Brown

"We need to take on anesthesia as a neuroscience question to address how we can develop very precise ways to control the delivery of anesthesia so the person gets just enough — not too much or too little."

Long before Emery N. Brown chaired Massachusetts General Hospital's recent 175th anniversary celebration of the first public demonstration of ether anesthesia, he was thinking deeply about how far anesthesiology has come and could still go.

Anesthetic drugs act on the brain, but the field has barely explored the innovations that could come from integrating neuroscience into anesthesiology practice, says Brown, Edward Hood Taplin Professor of Medical Engineering and Computational Neuroscience. A neuroscientific approach could reduce side effects, make drug delivery more precise, manage postoperative pain better, and usher in new treatments for sleep or methods for coma recovery.

Brown performs neuroscience and statistical research in The Picower Institute for Learning and Memory and the Institute for Medical Engineering and Science and puts it into practice as an anesthesiologist at MGH. Now he is launching a new research center. David Orenstein at The Picower Institute asked him to discuss these ideas.

Q: After 175 years of history, what are the frontiers for anesthesiology now?

A: The first public demonstration of ether anesthesia at MGH was really the start of a new era in medicine. It changed surgery overnight from being a trauma to being a reasonable and life-saving therapy. The focus of research at the time had been on coming up with better contraptions to hold you down so they could conduct a surgical procedure without anything to effectively mitigate the pain. In this regard, the field has come quite a long distance.

On the other hand, the neuroscience of anesthesia has been slow to be developed. That's what we've been working on over the last several years and I think that's where I see the future being. The frontier in anesthesiology lies in neuroscience.

Q: What has your recent research shown about the neuroscience of anesthesia?

A: We now have a lot of detailed, hard data showing that anesthetic drugs create oscillations in brain circuits that impede the ability of various parts of the brain to communicate.

In recent work with my colleague Earl Miller, we came to appreciate how far away the dynamics of brain oscillations under anesthesia are from the dynamics the animals showed when conscious. You dramatically alter how much the neurons spike. What propofol is doing is slowing down brain oscillations to create an alternate dynamic, one which doesn't allow you to be conscious. The same thing is true with ketamine, but instead of the brain being slowed down, slow activity oscillates with faster activity at a very regular pace. This is also a dynamic that is quite far from the dynamic we see when an animal is conscious.

Illustration: Ellen Weinstein

So becoming unconscious with anesthetics is not so much about turning the brain off as changing the dynamics. We see this in humans, too, and that's extremely helpful to us, because now I can interpret the oscillations I see when a patient is anesthetized in the operating room. I have very good neurophysiological evidence as to why I should feel comfortable the person is unconscious in those conditions. We can measure these oscillations in real time via EEG. I do it with all my patients. I'm encouraging colleagues to do it as well.

Q: What advances do you hope to develop in the new center?

A: I couldn't be more excited about setting up the center because neuroscientific ideas can be turned into new approaches to taking care of patients.

For example, those oscillations that are part of the mechanism through which anesthetics induce unconsciousness are also part of the mechanism through which the drugs contribute to brain dysfunction after surgery, which we know is highly prevalent in older patients. What we have to do is develop alternate ways to inactivate circuits, so that we can create the states and do away with the side effects.

We need to take on anesthesia as a neuroscience question to address how we can develop very precise ways to control the delivery of anesthesia so the person gets just enough — not too much or too little. How can we develop procedures to accurately read and interpret the EEG during surgery, so the anesthesiologist can reliably know when a patient is unconscious? How can we develop accurate ways of measuring the level of nociception, meaning pain that a patient is perceiving during surgery, so we can more accurately titrate analgesics during surgery? How do we work out ways to turn brain communication back on so that we can restore functionality once someone's anesthesia is completed?

A long-range goal will be to have very site-specific methods to activate or inactivate only the brain regions and circuits that are necessary and leave the other areas untouched. To do this we need deep neuroscience and engineering expertise. What better place than MIT in collaboration with our clinical colleagues at MGH? It's the perfect marriage, if you will.

There's even greater potential as we learn fundamental things about the brain from studying how anesthesia affects interregional communication and inhibitory networks. We can develop better ways to control the on and off of brain communication. Maybe that's a new approach for helping someone sleep better or if we're able to reboot the brain from a very fundamental level, maybe that's a way to help foster coma recovery.

For more than 20 years, George Elbaum '59 and his wife, Mimi Jensen, have been champions of the School of Science research enterprise by providing fellowship support for graduate students in physics and EAPS. Recently, Elbaum heard a talk by Dr. Emery Brown about how current anesthesia practice does rely on or employ any tools of modern neuroscience. "I feel like an explorer that all of a sudden discovers a new continent, and I'm just amazed by this," says Elbaum who was dumbfounded that anesthesiologists are trained in clinical pharmacology but not in neuroscience. "I'm in my 80s but I wish I was 60 years younger and starting grad school because I am thinking, 'Hey, I want to get into this!'" he says.

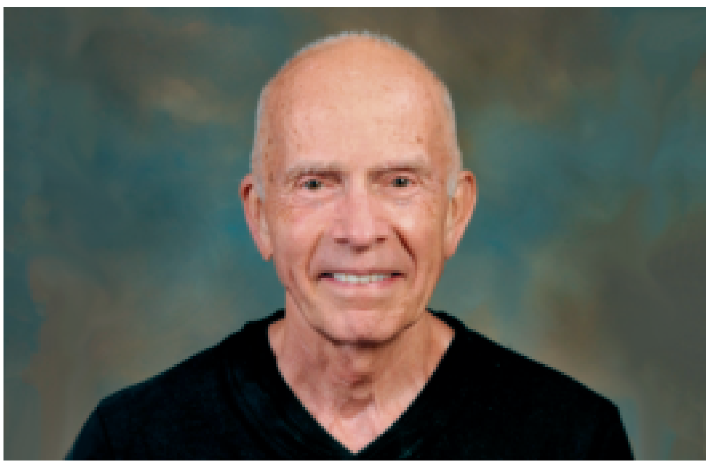
Though Elbaum says restarting graduate school might not be in the cards, he did the next best thing. He wrote a check for $100,000 in support of Brown's laboratory. Elbaum and Jensen also pledged to provide resources for the next five to 10 years so Brown can continue to uncover the links between general anesthesia and clinical neuroscience. "This is a fantastic opportunity for mind-blowing research," he says.

George Elbaum and Mimi Jensen
Photo: Marc Longwood

Life sciences at MIT is unmatched

Paul Schimmel and family's recent donation can match up to $25 million in additional funds to support life sciences at MIT

Julia C. Keller | School of Science



Paul Schimmel
Photos: courtesy of the researchers

Phillip Sharp

This past August, the Department of Biology and the School of Science announced the creation of the Schimmel Family Program for Life Sciences at MIT as a result of the $50 million dollar donation from Professor Emeritus Paul Schimmel PhD '66 and his family. Half of this support is designated to be matched with donations from other supporters of the department and the life sciences research enterprise. Now, with a recent donation from Institute Professor Phillip Sharp — a friend of the Schimmels and another lifelong supporter of biology — the matching funds, and opportunities for life sciences research at MIT, continue to be unlocked.

"The life sciences educational enterprise spreads across a dozen departments at MIT," says Schimmel of the impact of this giving. "What makes the Biology Department and the life sciences at MIT so extraordinary is the singular ability to transfer knowledge and inventions to society for its benefit."

Schimmel and Sharp, well-matched

In August 2020, the Schimmel family committed $50 million to support the life sciences at MIT. The family's initial gift of $25 million established the Schimmel Family Program for Life Sciences and was matched with $25 million secured from other sources in support of the Department of Biology. The remaining $25 million from the Schimmel family now serves as matching funds for future gifts supporting the life sciences. To date, $7 million in new gifts from other donors have been committed toward this effort, eliciting an additional $7 million in matching funds from the Schimmel family.

Professor Sharp is among those supporters who have joined his former colleague and friend, Paul Schimmel.

"Paul and I taught together, shared an interest in RNA biology, and have remained close friends since his move to Scripps Institute," says Sharp of his career-long friendship with Schimmel, who is the Ernst and Jean Hahn Professor at the Skaggs Institute for Chemical Biology at the Scripps Research Institute.

Though Schimmel formally left MIT for the Scripps Institute in 1997, he remained actively involved in supporting MIT's research enterprise, with a particular focus on MIT graduate students, through his role on the Biology Visiting Committee.

Sharp and Schimmel agree that the success of graduate students remains key to the long-term sustainability of the life sciences at MIT. "We share a passion for supporting and engaging with the next generation of outstanding biologists, scientists, and leaders — well represented among MIT graduate students," Sharp adds.

Sharp's donation — matched by the Schimmel family gift — provides funds to establish fellowships for biology graduate students. "I hope others will join me in supporting the biology department and life sciences here at the Institute through the Schimmel family matching opportunity, as their investment will impact students and research for generations to come."

Match point

"I am extremely grateful to Paul, his family, and Professor Phillip Sharp and Ann Sharp for their generosity and helping to inspire others to follow their lead," says Biology Department Head and Praecis Professor of Biology Alan Grossman.

Grossman has worked with Sharp and the Schimmels for many years and is keenly aware of the important role these gifts play in a time of dwindling government investment in the sciences.

"As federal support for graduate training continues to wane over time, support from individuals like Paul, Phil, and others becomes crucial to the future of the life sciences," Grossman says. "As COVID-19 has laid bare, there has never been a more critical need or better time to invest in basic science than right now."

With $18 million remaining in available matching funds, Grossman says that he and partners throughout MIT continue to seek out others who wish to contribute to and participate in the Schimmel Family Program for Life Sciences. "Providing students with the resources they need to be successful in their education, research, and careers remains at the core of our mission," says Grossman.

"Paul and the Schimmel family have provided other donors with an extraordinary opportunity to amplify the impact of their giving by leveraging their vision for the betterment of life sciences at the Institute," says Biology Director of Development Daniel Griffin. "This initiative is resonating with people in and outside of the MIT community and we are all excited to see where it leads."

Peter Fisher appointed the inaugural Thomas A. Frank (1977) Professor of Physics

Elizabeth Chadis | School of Science

In early 2021 Peter Fisher, head of the Department of Physics, was named the Thomas A. Frank (1977) Professor of Physics, a newly endowed chair made possible by the generosity of alumnus Tom Frank.

When asked how it felt to be a chair holder, Fisher said, "I like it. I like that I actually know Tom, and I do feel honored to be the Thomas A. Frank (1977) Professor of Physics."

About the same age, Fisher and Frank grew up on different U.S. coasts: Fisher in Marin County, California, and Frank on Staten Island, New York. Both men share a love of programming, computers, and ultimately, physics.

As youngsters, both Fisher and Frank played with early hobbyist computers. Fisher had an HP-65 programmable handheld calculator and thrilled to the magnetic cards that allowed him to program. Frank had a Rube Goldberg machine, a DigiComp I that fired his imagination, and still has his battered and worn PDP-11 handbook. (Frank and Fisher say they both agree that DEC's PDP-11 was the best 32-bit computer ever made.)

In the sixth grade, Frank decided he would attend MIT when he grew up, and, eventually, he did so. Fisher applied to MIT after reading an *MIT Technology Review* article on the Institute's hunt for the Loch Ness Monster, but he did not get in. Instead, he attended the University of California at Berkeley, and studied engineering physics, although he was

Alumnus Thomas Frank (left) and Department Head Peter Fisher (right) talk at a physics event held prior to Covid-19.
Photo: courtesy of the MIT physics staff

really more interested in computing. His love of computers led him to high-energy physics. Why? "Because they had the best computers," Fisher says.

When Frank matriculated to MIT, he first checked out the Center for Theoretical Physics (CTP). Although he developed a relationship with Professor Francis Low, CTP director, he ultimately chose experimental particle physics. In 1977, Frank completed his bachelor of science degree, and subsequently a PhD under the supervision of Professor Dick Yamamoto, a physicist whose work revealed the interactions of subatomic particles. Yamamoto worked on many experiments at Fermilab in Batavia, Illinois, where Frank spent much of his time as well, saying he found that "they still believed it was 1945 — that physicists could do everything."

At other labs such as CERN, there were slews of engineers that built things for you; but at Fermilab, notes Frank, "you had to do it all yourself. Anything I wanted to learn about, I could." Fisher also has a passion for particle physics, being recruited to MIT by Nobel Laureate Samuel Ting in 1994; and Fisher also worked closely with Yamamoto. For the past 25 years, Fisher has been on a relentless search to detect dark matter.

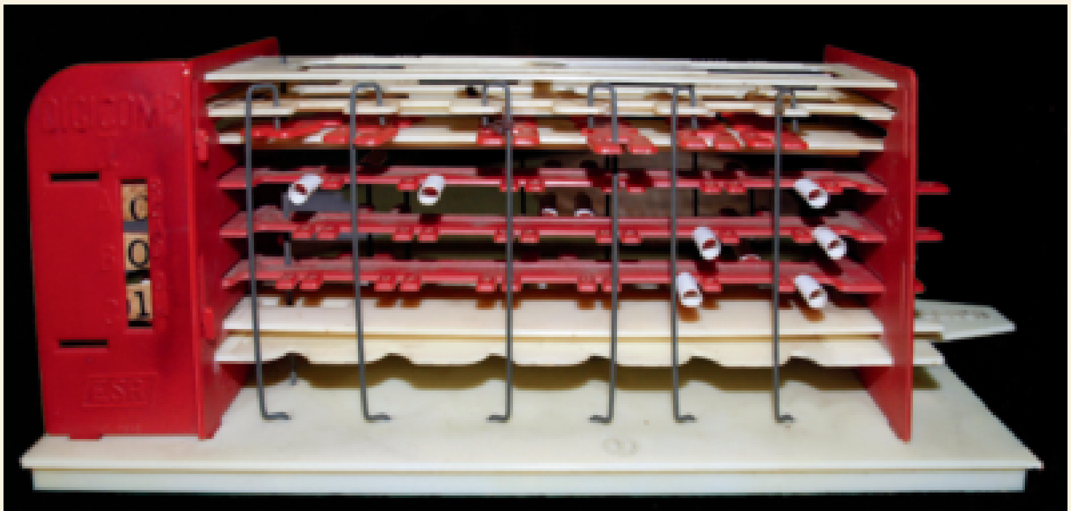
For his part, Frank realized halfway through his graduate program that an academic career was not for him. In his last year, he interviewed with a few banks; and then was introduced to Thomas Peterffy, a digital trading pioneer who wanted to put Wall Street on a chip. On the way to the interview, Frank says he read a book about stock options — but it didn't really matter. "We talked for hours about everything but options and then he offered me a job on the spot," Frank says of his conversation with Peterffy, founder and chairman of the Interactive Brokers Group. Frank joined Interactive Brokers in 1985 with his newly minted doctorate from MIT; and since 1999 has been the company's executive vice president and chief information officer.

Everyone agrees that appointing Fisher as the inaugural Thomas A. Frank (1977) Professor of Physics is a great match. Nergis Mavalvala, dean of the School of Science, says she thinks Fisher is one of MIT's unsung heroes. "When the pandemic forced us to send people home, it was Peter who offered a lifeline to the community through his daily email letters of encouragement, compassion, and true leadership."

In addition to the professorship, Frank has been supporting physics graduate students with fellowships for almost two decades. For Frank, he says, "it is a privilege to be able to contribute to the great things happening in the Physics Department at MIT."

A version of this article originally appeared in the 2021 annual issue of Physics@MIT.

The DigiComp I was a mechanical digital computer sold in the early 1960s in the United States. Educational toys such as this one set Thomas Frank on the path from computation to particle physics, and, subsequently, to Wall Street.
Photo: Pterre, CC B-SA 3.0, via Wikimedia Commons https://commons.wikimedia.org/wiki/File:Digicomp_I.JPG



Arlene Fiore appointed first Stone Professor

Fiore brings expertise in climate science, atmospheric chemistry, and air pollution

Lauren Hinkel and Alice McBride | Earth, Atmospheric and Planetary Sciences

The MIT Department of Earth, Atmospheric and Planetary Sciences (EAPS) has named atmospheric chemist Arlene Fiore the Peter H. Stone and Paola Malanotte Stone Professor in Earth, Atmospheric and Planetary Sciences. Her chair began on July 1.

Fiore is the first person to be appointed to this senior position, a full professorship that was generously endowed to EAPS by Professor Emeritus Peter H. Stone and Professor Paola Malanotte-Rizzoli. The couple's $5 million donation sparked a multiyear campaign to find a suitable candidate to fill this prestigious named chair, intended to attract top scientists and enhance the department's contributions to research, teaching, and mentorship in atmospheric sciences, physical oceanography, climate sciences, or planetary sciences.

The recruitment committee found a winning combination in Fiore, who brings with her 25 years of experience in the geosciences. She specializes in understanding how polluting emissions from anthropogenic and natural sources influence atmospheric chemistry, the climate system, and air pollution on regional to global scales, as well as the drivers of these interactions.

Arlene Fiore
Photo: Steph Stevens

"I am immensely grateful for the gift by Peter Stone and Paola Malanotte-Rizzoli — long-term colleagues and friends of EAPS — and excited to welcome Arlene into the EAPS community," says head of EAPS Rob van der Hilst. "Professor Arlene Fiore brings unique expertise to the EAPS climate program, at a time when MIT is ramping up its efforts to understand the underlying Earth systems and create solutions for mitigation and adaptations to climate change. Combined with her accolades in teaching, mentorship, and organization in support of women and diversity, she is a huge asset to our research, education, and outreach programs."

Fiore comes to EAPS from the Department of Earth and Environmental Sciences and Lamont-Doherty Earth Observatory of Columbia University, where she breaks her research down into four pillars: air pollution, chemistry-climate connections, trends and variability in atmospheric constituents, and biosphere–atmosphere interactions. She uses a range of models alongside remote sensing and in situ observations to understand tropospheric ozone chemistry, its sensitivity to different sources and sinks including the terrestrial biosphere, on hourly and local scales up to global and decadal dimensions. Fiore and her group also investigate regional meteorology and climate feedbacks due to aerosols versus greenhouse gases, future air pollution responses to climate change, as well as the factors controlling the oxidizing capacity of the atmosphere. As a member of the NASA Health and Air Quality Applied Sciences Team, she partners with air and health management groups to address emerging needs with applications of satellite and other Earth science datasets.

Since earning her undergraduate and PhD degrees from Harvard University, Fiore held a research scientist position at the National Oceanic and Atmospheric Administration's Geophysical Fluid Dynamics Laboratory before joining Columbia University. She has since served on numerous boards and earned several awards. Among these are participating on the board of the Atmospheric Sciences and Climate of the National Academy of Sciences, the U.S. CLIVAR Working Group on Large Initial-Condition Earth System Model Ensembles, the American Meteorological Society Statement on Atmospheric Ozone, and the Steering

Department of Earth, Atmospheric and Planetary Sciences head Robert van der Hilst (left) converses with Professor Emeritus Peter H. Stone and Professor Paola Malanotte-Rizzoli at a celebration of the Stone Professorship in 2015.
Photo: J. Gillooly

Committee for the IGAC/SPARC Chemistry-Climate Model Initiative. Fiore's honors include the AGU James R. Holton Junior Scientist Award, AGU's James B. Macelwane Medal, and the Presidential Early Career Award for Scientists and Engineers (PECASE), which is the highest honor bestowed by the United States government on outstanding scientists and engineers in the early stages of their independent research careers. She is one of six co-founders of the Earth Science Women's Network, promoting peer mentoring, career development, and equality in the geosciences.

"I enjoy studying interactions across realms that have in the past been considered separately — such as the climate system and air quality, urban air pollution and global atmospheric chemistry, the stratosphere and troposphere, terrestrial biosphere and atmosphere," says Fiore. "Currently, I'm excited about a new research direction that seeks to identify imprints of climate variability on short, sparse observational records of trace gases, so that we can better detect and attribute the influence of human activities on atmospheric composition and climate."

Further, at MIT, she looks forward to inspiring the next generation of problem solvers to understand atmospheric chemistry and climate system data, and equipping them to develop and leverage new computational methods.

"Fiore is an accomplished researcher in several areas, especially the linking of atmospheric chemistry with climate change phenomena such as changes in rainfall and heat waves," says Susan Solomon, the Lee and Geraldine Martin Professor of Environmental Studies at MIT. "EAPS has a lot of strengths in atmospheric chemistry, as well as plenty of depth in climate dynamics and meteorology. Fiore's conversations with both have been positively electric, and we expect great new linkages to amplify our science impacts after she arrives."

Stone and Malanotte-Rizzoli see the greatest challenge of the 21st century to be climate change, making research in the geosciences front and center at this point in history. As such, they endeavored to continue the "tradition of excellence in atmospheric, climate, or planetary sciences," at MIT.

At a reception honoring the generous endowment in 2015, van der Hilst described Stone and Malanotte-Rizzoli as "inspirational leaders," whose gift not only strengthens the department but also bestows the unique "privilege of having their names forever associated" with EAPS. Both Stone and Malanotte-Rizzoli hold numerous awards and honors for contributions to their fields, and are renowned for their dedication to research and teaching alike.

Combined, Stone and Malanotte-Rizzoli have contributed 75 years of active service to the Institute and department. Stone first joined MIT in 1972 as a visiting professor of meteorology, and went on to become department head, director of MIT's Center for Meteorology and Physical Oceanography, and director of the MIT Climate Modeling Initiative. He was at the forefront of atmospheric and climate dynamics research throughout his career, right up to his retirement in 2007. Malanotte-Rizzoli came to MIT in 1981 as an assistant professor of oceanography. While her physical oceanography interests are varied, she was named professor of physical oceanography in 1992, and spent 12 years directing the graduate-level MIT-Woods Hole Oceanographic Institution Joint Program in Oceanography and Ocean Engineering. Malanotte-Rizzoli has also been a tireless voice in promoting gender equality among faculty at MIT.

On the selection of Fiore to the post, Malanotte-Rizzoli says, "we wish to see superb scientists and teachers, not limited to a very specialized scientific sector but who can cross, with equal excellence, disciplinary boundaries, and build a new generation of researchers capable to do so. Arlene Fiore is such an example."

"We're very grateful for the chance to bring in an accomplished senior climate person to MIT — especially at this special moment in history when MIT is marshaling its abilities to help address the climate challenge," says Solomon. "The timing couldn't be better for strengthening the already considerable climate arsenal in EAPS!"

Chemist and Martin Luther King Jr. Scholar Robert Gilliard explores new frontiers in synthetic chemistry

MIT visiting scholar motivated foundational science at the edges of the periodic table

Leah Campbell | School of Science

Almost 15 years ago, Robert Gilliard posed for a photo in front of MIT's Great Dome. At the time, he was an undergraduate at Clemson University visiting MIT with his research advisor, former MIT postdoc and Clemson University professor, Rhett Smith. Just last month, Gilliard arranged a similar photo in front of the dome. This time, though, he was the professor behind the camera, wrangling his own students. And now, Gilliard is back working in experimental chemistry alongside MIT Dreyfus Professor of Chemistry "Kit" Cummins with the 2021–22 cohort of Martin Luther King (MLK) Visiting Professors and Scholars.

As an MLK Scholar at MIT, he's one of nine professors, in research areas ranging from art to engineering, selected for outstanding contributions in their fields to increase the presence of underrepresented minority scholars at MIT.

In the decade since his first visit to MIT, Gilliard has become one of the brightest young scholars in chemistry. Most recently, he's won a Packard Fellowship, an Alfred P. Sloan Research Fellowship, a grant from the Beckman Foundation Young Investigator Program, and a National Science Foundation CAREER Award. He was also named to the 2020 class of the Talented Twelve, an elite list of scholars identified by *Chemical & Engineering News* as rising stars in the world of chemistry.

Currently, Gilliard is an assistant professor of chemistry at the University of Virginia (UVA). He arrived at UVA after completing his PhD at the University of Georgia and a joint postdoc at ETH Zürich in Switzerland and Case Western Reserve University. Even before arriving at UVA, he had built up an impressive résumé, having received postdoctoral fellowships from both the Ford Foundation and the UNCF-Merck Science Initiative dedicated to supporting the training and development of African American biomedical scientists.

Despite his accomplishments, Gilliard humbly describes his professional path as essentially unplanned. He always liked science but admits that he was never "one of those kids with the chemistry set." In fact, he enrolled at Clemson

MLK Visiting Professor and Scholar for 2021–22, Robert Gilliard (right), works with MIT's Christopher Cummins (left) to synthesize new chemical molecules from the edges of the periodic table, while prioritizing collaboration and student mentorship. *Photo: Allegra Boverman* as pre-med. But it took only one day for him to switch to engineering and only one semester to go from engineering to chemistry. Getting to do research as an undergraduate was the moment that his enjoyment of science became a desire to be a scientist.

Today Gilliard's lab is pushing the boundaries of synthetic chemistry. He focuses on what are called main-group elements, those elements on the edges of the periodic table like boron and beryllium that have been traditionally understudied by chemists.

"Main-group elements do a lot we didn't know they could do," according to Gilliard. "I think we are just now beginning to scratch the surface of what's possible for these elements."

Most of his research falls into two buckets. The first is what chemists call small molecule activation, in which they use relatively simple molecules to create new compounds that might be industrially useful. For example, Gilliard's lab is focused on creating compounds that react with carbon dioxide, which could, in turn, help recycle the potent greenhouse gas from the atmosphere.

The other bucket of research is focused on thermochromic and thermofluorescent compounds, ones that can change color or light up depending on the temperature. Creating molecules that can visibly react to temperature changes provides a way to track ambient conditions without expensive analytical equipment, and, according to Gilliard, the applications for such compounds are endless. For example, soldiers could have uniforms that change color based on terrain they're in. More immediately, the packaging around COVID vaccines, which need to be stored at a certain temperature, could be developed to change color if it gets too warm and the vaccine is compromised.

Gilliard has no trouble describing potential applications to the compounds his lab is creating, but, for him, applications aren't the priority. He's motivated by the fundamental science, by the experimentation, and by the opportunity to create novel molecular structures and bonds that will have applications we can't possibly predict.

"A lot of times in chemistry, you're looking for one thing," he says, "but then you find something that's way cooler and much more important."

It's no surprise, then, that he's developed a professional relationship with Cummins here at MIT. Like Gilliard, Cummins sees himself as an "exploratory" chemist focused on creating interesting new molecules that have never been written about or that challenge the tenets of theoretical chemistry.

Cummins is Gilliard's host during his visiting professorship. Cummins was the first seminar speaker Gilliard invited when he started at UVA and the one that introduced Gilliard to the MLK Scholars Program at MIT.

"Kit was just somebody who, throughout my time as a grad student and a postdoc, I just always, and I continue to, hold in such high regard," says Gilliard. "It's been a pleasure getting to know him even better since I've been here."

Cummins speaks equally highly of Gilliard and says that he knew the young professor was a great candidate for the MLK Scholars Program as soon as they met. The two attend each other's lab meetings and have already begun joint research combining the techniques that Cummins's lab has developed with the novel molecules coming out of Gilliard's work. Cummins hopes that their collaboration will result in interesting new chemical linkages that can have optical applications and catalyze other kinds of new reactions.

Cummins likens their relationship to a Reese's Peanut Butter Cup: "two things that are great on their own, but they're even better together." He's been thrilled to have Gilliard bring his insight to the lab and help his team brainstorm exciting new ideas and avenues for research.

"Sometimes my approach to science is a bit more analogous to improvisational jazz," Cummins jokes. "I've always been so happy at MIT that there's space for people like me and Robert who look at science in that way and view it as an outlet for our creative juices."

Despite his accomplishments, Gilliard is quick to turn the conversation to those around him, like Cummins, who have helped him get to this point in his career. Even before becoming a professor, there was the high school science teacher, Charlotte Godwin, who encouraged him with hands-on experiments and with whom he remains in contact. There was the professor at Clemson, Lourdes Echegoyen, who recommended he should give chemistry a try. And there was his undergraduate research advisor on whom Gilliard has modeled his own mentoring style. He also credits much of his success to the students in his lab, every one of whom he continues to meet with every week.

"I think one of the reasons why we have been able to produce the amount and quality of research that we've been able to produce is because we are in constant contact with each other," Gilliard says. "We are able to solve problems faster together."

Unsurprisingly then, Gilliard's response when asked about his recent litany of accolades was simply, "I'm just happy for the students.

Paying back a debt with "exploration capital" for MIT Math

Alumnus Stephen Berenson '82 creates the Mathematical Exploration Fund to support bold research by students and faculty

Leah Campbell | School of Science

"I have always felt like I owe a debt to MIT for having taken a risk on me."

Whatever risk he thinks he presented at the time, Stephen Berenson '82, certainly took advantage of the educational opportunities he was given at MIT. After two years as a transfer student, majoring in mathematics, Berenson went on to have a successful, three-decade career in investment banking. Today, he is a managing partner at Flagship Pioneering, a life sciences innovation firm based in Cambridge, Massachusetts.

Berenson has been a longtime supporter of the Institute to, in his words, pay back his debt of gratitude. Now he's given his largest gift yet by establishing the Berenson Mathematical Exploration Fund. The fund will support students and faculty in the department doing research that is hard to fund through traditional funding channels. Berenson describes it as "exploration capital."

"We're eager to begin seed projects within the department," says Michel Goemans, the RSA Professor of Mathematics and head of the Department of Mathematics. "Stephen's transformative gift will support our faculty and students, and hopefully lead to new mathematical avenues to explore."

The path that brought Berenson to this point has been a bit circuitous at times. He laughs recalling his bad luck with college applications and the wrangling it took as a high school senior to get into his safety school. After two years, though, feeling wholly uninspired, he transferred to MIT.

"I still remember the moment when the MIT light bulb went on," he says, describing perusing an MIT course catalog on his family's kitchen table. It belonged to his younger sister, who was doing college research. "I started flipping through it, and an hour later when I was done, I said, this is where I have to be."

Berenson was inspired by what he describes as the overwhelming breadth and depth of the offerings in that catalog, especially in mathematics and physics, his fields of interest. That summer after his sophomore year, he applied to MIT, securing his acceptance mere days before the new semester started.

Though he clearly came in with a certain knack for abstract thinking and generalization, Berenson says that those skills were amplified by faculty in the Department of Mathematics. He can still identify several faculty members who had a particular impact on him.

Stephen Berenson

Berenson credits James Munkres, now an emeritus professor, for teaching him a whole new level of discipline in his thinking. He also lauds professors Michael Artin and Sigurdur Helgason, both now emeriti, as essential for nurturing his creativity and intellectual development in those two years at MIT.

"They just allowed my mind to roam," says Berenson. "They were giants in their fields, and yet really willing to give their personal time to an eager junior or senior, which was very meaningful."

After graduation, Berenson took a somewhat unconventional path again, spending about six months saving up money and then living in Nicaragua for almost a year. At that end of that, he found his way to investment banking.

Berenson admits that during his professional career, he hasn't used much of the math he learned at MIT. He started at JP Morgan in 1984, where he stayed for 33 years, before moving over to Flagship Pioneering in 2017. Yet, he recalls his answer when asked explicitly during a job interview how his "fancy math degree" would help him as a banker. "I know the difference between fact and assumption," he responded.

At the time, Berenson admits it was a somewhat flippant answer, but, after a long career in banking, he understands just how prescient it was. He also sees other indirect ways his mathematical education at the Institute has shaped his career.

"In terms of disciplined thinking, logical thinking, care and attention to detail, the ability to engage in abstract thinking, and generalization of problems, it helped me immensely," says Berenson.

"I want to enable for the Math Department research that at the outset may seem unreasonable to give incremental opportunities to smart, motivated professors and students to make leaps and see where that leads them."

Appreciating just how important his time in the Department of Mathematics was for his development motivated Berenson to establish the Mathematical Exploration Fund. It's one of several ways in which Berenson has given back to the Institute including creating a scholarship fund; being an ongoing supporter of the Department of Mathematics' Program for Research in Mathematics, Engineering and Science for High School Students (PRIMES); serving on the Department of Mathematics Visiting Committee; and contributing to the recruitment team for JP Morgan for 20 years, bringing on many MIT students. Now with the Exploration Fund, Berenson has made a gift of support specifically for the research within the department.

"It is nice to hear Stephen reminisce about all the cool math subjects he took while majoring in math at MIT," says Goemans, "and clearly this rigorous math training has served him well in his career."

Berenson stresses that he developed the gift in partnership with Goemans. While he came in with some notions of how the funds could be deployed, it was important for him to understand the department's priorities and identify where the funds could have the greatest contribution.

"I want to enable for the Math Department research that at the outset may seem unreasonable," says Berenson, "to give incremental opportunities to smart, motivated professors and students to make leaps and see where that leads them."

It's an appropriate sentiment for an alumnus whose journey to MIT and every step since has been about taking big leaps.

PRIMES reaches prime number 11

Sarah Costello | School of Science

In 2021, MIT marked the 11th anniversary of the launch of PRIMES, the MIT Program for Research in Mathematics, Engineering and Science for high school students. Led by chief research advisor, Professor Pavel Etingof, the free afterschool program attracts talented high schoolers from the greater Boston area and beyond who pursue original research with mentorship from MIT scholars. Over the past 11 years, PRIMES students made exceptional progress in mathematics, computer science, and computational and physical biology.

Since 2015, PRIMES has reached 70 percent of a $5 million endowment goal. Through generous gifts, PRIMES has strengthened programs, created named mentorships, and expanded offerings. MIT professor Daniel Stroock recently provided a gift to pilot an expansion of PRIMES-USA — the long-distance mentoring version of PRIMES for students outside the Boston area — to include sophomores in addition to juniors.

MIT alumni support has also been crucial. Stephen Berenson ’82 has been a longtime supporter of PRIMES (see “Paying back a debt with ‘exploration capital’ for MIT Math” on page 14). John “Jack” N. Little ’78 president and founder of MathWorks, provides much of the operational costs for MathROOTS, a two-week summer program for nationally selected students. Victor Menezes SM ’72 created the Victor J. Menezes (1972) Challenge Fund in Mathematics to help support MathROOTS and PRIMES Circle. The Menezes Challenge PRIMES Circle is a local section dedicated to helping students develop their interest in mathematics and setting them on a path toward a math-based major in college. The program tripled from eight students in 2013 to 24 in 2021.

PRIMES pairs high school students with MIT graduate students and postdocs to investigate unsolved problems in mathematics, computer science, and computational biology.
Photo: courtesy of the Department of Mathematics

The success of these two programs targeting talented students from underrepresented groups was recognized with a MIT 2021 MLK Leadership Group Award for "deep and coordinated commitment to improving diversity in mathematics."

The PRIMES proof is in the pudding — and in the research papers. In 2021, 120 students presented on their projects during PRIMES conferences. Moreover, students produced 66 research papers in 2020–21, bringing the total PRIMES papers to 284, with 61 published in academic journals or conference proceedings.

In national news, Yunseo Choi won first place and Gopal Goel fourth place in the 2021 Regeneron Science Talent Search, earning them $250,000 and $100,000 scholarships, respectively. Jessica Zhang won the second Grand Award in Math and the first Special Award from the American Mathematical Society at the 2021 Intel International Science and Engineering Fair. William Li won the third Grand Award in Math and an Honorable Mention from the American Mathematical Society.

PRIMES has formed a pipeline through which former students become mentors for a new generation of mathematical talent. Five alumni are currently math graduate students at MIT. Jonathan Tidor (PRIMES '12, '13; MIT '17), is a graduate student who serves as a mentor in the Department of Mathematics' Summer Program for Undergraduate Research (SPUR). He and his student shared the 2021 Hartley Rogers Jr. Prize for the best paper during the 2021 SPUR program.

Several other MIT mentors were recognized in 2021. The George Lusztig mentorships, funded by a contribution from MIT mathematics professor George Lusztig, were awarded to two PRIMES mentors, Chun Hong Lo and Adela Zhang, and PRIMES Circle coordinator Peter Haine. The Michael and Victoria Bershadsky mentorship was awarded to mentor and MathROOTS program director Andrey Khesin. Finally, the Menezes Challenge Mentorship in the MathROOTS program was awarded to math lecturer and head mentor Tanya Khovanova.

Out of 332 PRIMES alumni who reported their matriculation data, 45 percent enrolled at MIT, 21 percent at Harvard, and 7 percent at Stanford. Further, the quality of PRIMES applicants to MIT is growing: Last year MIT admitted more than 75 percent of PRIMES applicants.

> **"Moreover, students produced 66 research papers in 2020–21, bringing the total to 284..."**

Yunseo Choi places first in the 2021 Regeneron Science Talent Search.

This year, Sean Li won a $10,000 scholarship from the Davidson Institute and will be attending MIT next fall as a prospective math major in the class of 2026. "In a perfect world, I'd grow up to be a professor," says Li. "I'd be teaching and researching, and I'd get paid for it!"

Championing the brain

Supporters gather for annual event celebrating excellence and innovation in the Department of Brain and Cognitive Science

Leah Campbell | School of Science

This October, faculty, students, and supporters of the Department of Brain and Cognitive Sciences (BCS) gathered for the eighth annual Champions of the Brain Fellows reception. For the second year in a row, the event was held virtually. But no Zoom hiccups could stop the department from hosting a rousing celebration of the exciting research being done by BCS graduate students — and the department champions who help make it possible.

The event began with opening remarks by the dean of the School of Science Nergis Mavalvala thanking the supporters who “make it possible for us to train the next generation of scientists.” She then introduced Department Head Michale Fee, the Glen V. and Phyllis F. Dorflinger Professor of Brain and Cognitive Sciences.

Fee highlighted the vision of the BCS Department to undertake groundbreaking research — both basic and applied — to understand how the human brain works at all levels. He positioned graduate students as the “engine” of the department and stressed the need for stable, centralized funding to foster the “mind-blowing” research they do.

“Sustaining our vision means building an outstanding community of faculty, students, and researchers, and ensuring they have the support and resources to continue making the great discoveries that they make every day,” said Fee.

Fee then introduced three students who have all benefited from fellow funding this year to give a taste of the “wide range and amazing questions” on which BCS students work.

First up was Greta Tuckute, a second year student in the lab of Evelina Fedorenko, the Middleton Career Development Professor of Neuroscience. Tuckute is supported this year by BCS champion Eran Broshy ’79 and studies the combination of brain regions called the language network. It’s been difficult historically to study the development of the language network since most developmental leaps occur in toddlers. Tuckute presented a case study of an adult woman who is missing her left temporal lobe, a region of the brain crucial to language development.

“Sustaining our vision means building an outstanding community of faculty, students, and researchers.”

Tuckute found no language activity in the woman’s left frontal lobe, suggesting that temporal regions of the brain are necessary to wire up the later-developing frontal regions of the language network. However, according Tuckute, apart from not having a left temporal lobe, the woman is completely neurotypical (and has even learned a foreign language), illustrating that a fully functioning language network can develop with just one hemisphere of the brain.

The next presenter was Djuna von Maydell, a third-year student in the labs of Professor Li-Huei Tsai and Manolis Kellis a professor of computer science at MIT’s Computer Science and Artificial Intelligence Lab. Von Maydell is supported by BCS champions Nancy and Jeffrey Halis ’76. Her work focuses on a mutation in the APOE4 gene that’s one of most prevalent genetic risk factors for Alzheimer’s disease and changes the structure of a molecular protein that’s crucial for brain function. She’s found that the mutation causes cholesterol to be distributed throughout cells, rather than concentrated along the cell membrane as expected, particularly in what’s called oligodendrocyte cells. This ineffective distribution of cholesterol could be limiting the ability of those cells to do their jobs of helping neurons in the brain fire efficiently, leading to some of the deficits associated with Alzheimer's.

The final presenter was Karla Alejandra Montejo, a second year in the lab of Dr. Emery Brown, the Edward Hood Taplin Professor of Medical Engineering and Computational Neuroscience. Montejo is supported by BCS champions Russell '84 and Beth SM '84 Siegelman. She uses statistical models to understand patterns of brain activity under anesthesia. Montejo is interested in the metabolic effects of anesthesia, and how the availability of energy in brain cells can explain patterns of brain activity in a state of deep unconsciousness. Understanding the drivers behind patterns of brain signals during different phases, especially deep unconsciousness, can help researchers and anesthesiologists understand potential side effects of anesthesia, including the cognitive deficits some patients experience when they regain consciousness.

After breakout sessions to allow faculty, students, and supporters to engage with one another in a small group setting, Barrie Zesiger, an MIT Corporation life member emerita and founder of the Champions of the Brain program, closed out the event. Zesiger's goal is to be able to give BCS students the security and comfort of full funding so they can continue to pursue bold research that pushes the bounds of the field.

"I want to honor the wonderful role that graduate students play in what I call the 'MIT innovation machine,'" said Zesiger.

The annual Champions of the Brain Fellows event honors donors who commit $70,000 or more through an endowed, expendable, or corporate gift to support graduate students at the forefront of cutting-edge research in BCS.

Seed funding helps science researchers bear fruit

Researchers from across the School of Science benefit from the John W. Jarve '78 Seed Fund for Science Innovation

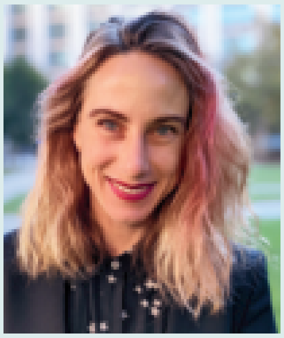
Leah Campbell | School of Science

John W. Jarve and Jacque Jarve
Photo: Marc Longwood

Seed funding may be something that comes up more often when talking about startups and tech companies, but it's just as important at a university. Internal funding provided by the Institute's schools helps researchers get projects off the ground and collect preliminary data to secure external funding from agencies such as the National Science Foundation and the National Institutes of Health (NIH) down the road. Just as with a startup, seed funding is an investment in projects and faculty that can encourage innovation and facilitate future success.

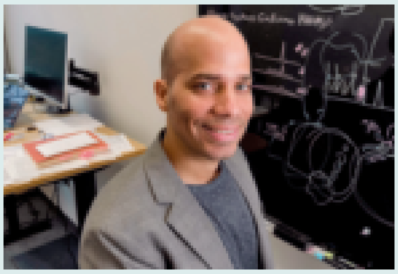
John W. Jarve '78, SM '79 a venture capitalist, knows the value of seed funding. Jarve is currently founder and CEO at Sierra Point Capital in Atherton, California. He's also a partner emeritus at Menlo Ventures, one of the first venture capital firms in Silicon Valley. He is life member of the MIT Corporation and former president of the MIT Alumni Association. Jarve and his wife Jacque are also life-long boosters for the MIT School of Science. Among his philanthropic efforts, Jarve has established scholarships for undergraduate students and endowed a professorship held by Associate Dean Rebecca Saxe in Brain and Cognitive Sciences.

Through the Jarve Seed Fund for Science Innovation established in 2019, the Jarve family has provided seed funding to support more than 20 research projects across the school. The most recent awardees and their seed fund projects are listed below.



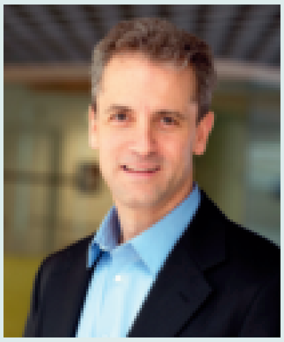
Polina Anikeeva is a professor in Brain and Cognitive Science, with joint appointments in Materials Science and Engineering and at the McGovern Institute for Brain Research. Her research focuses on developing new materials and devices to modify the signals moving between the brain, spinal cord, and throughout the nervous system. Anikeeva is using her seed funding to better understand the physical and chemical interactions between the brain and gut in Parkinson's disease.

Bonnie Berger is the Simons Professor of Math, with a joint appointment in Electrical Engineering and Computer Science, and a pioneer in the field of computational molecular biology. She used seed funding to expand her research using computational techniques, like deep learning, to help detect cancer-causing mutations within the human genome. The work Berger accomplished led to a peer-reviewed publication and several awards, including a featured plenary talk at the American Society of Human Genetics Conference in 2021.



Eliezer Calo, assistant professor of biology, studies ribosomes, the small particles found within cells that help create biological proteins and coordinate the activities of RNA, the single strand cousin of DNA. He's interested in how cells build these particles and how mutations in RNA can lead to disorders like cancer. With his seed funding, Calo used zebra fish to understand how ribosome function varies across different kinds of cells and whether that variety might affect how RNA is translated into proteins. The results from his study helped the lab secure a larger NIH grant to continue this work.

Joseph Davis, the Whitehead Assistant Professor of Biology, researches the mechanisms through which cells build and destroy the complex molecular machines inside them, including autophagy. Autophagy is when cells create a new structure to help destroy material around the cell as needed to maintain stability; and when autophagy fails, it can lead to diseases like Parkinson's and Alzheimer's. Seed funding has allowed Davis to apply new biochemical techniques to identify various proteins involved in autophagy as a first step toward understanding how those proteins function during the process and how they can fail.

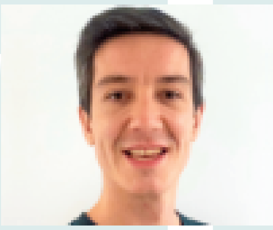


James DiCarlo is the Peter de Florez Professor of Neuroscience in the Department of Brain and Cognitive Sciences and director of the MIT Quest for Intelligence. He's using seed funding to investigate what role the amygdala plays in how humans react to stimuli and how that part of the brain determines the intensity and emotion of a reaction. DiCarlo has also used the funding to recruit a postdoctoral scholar, Alina Peter, and purchase equipment for the lab to begin a new project directly recording physiological reactions.

Mircea Dincă, the W. M. Keck Professor of Energy in the Department of Chemistry, creates and describes new chemical materials that can be used, among other applications, for energy conservation and storage and biotechnology. With seed funding, the Dincă lab has created an inventory of one-dimensional lattices held together by relatively weak electric forces. By identifying the diversity of properties of these new materials and how they evolve and interact with each other, he's developing easier methods to build nano-scale wires that can efficiently transport heat and electricity.

Ronald Fernando Garcia Ruiz, an assistant professor of physics, was jointly awarded seed funding with his postdoc, **Shane Wilkins**. The Garcia Ruiz lab uses laser spectroscopy to examine the radioactive properties of small atoms and molecules. With their seed funding, Garcia Ruiz and Wilkins are using those same radioactive particles to investigate the nuclear reactions that create new chemical elements within stars.

Ronald Fernando Garcia Ruiz



Shane Wilkins

Brent Minchew is an assistant professor in Earth, Atmospheric and Planetary Sciences and holds the Cecil and Ida Green Career Development Professorship. He is a geophysicist who uses geodetic data to understand glaciers, including how they respond to climate change, evolve over time, and shape the broader landscape. Minchew was awarded seed funding to improve projections of sea-level rise using machine learning of glacier dynamics.

Keith Nelson, the Haslam and Dewey Professor of Chemistry, researches the collective rearrangement and movement of all the molecules and ions within solid objects. With seed funding, he is expanding his work to understand a process known as "second sound," in which heat doesn't slowly diffuse through a space, but moves like a wave of light, leaving one space and transferring entirely to another. With seed funding, Nelson has been able to observe second sound at temperatures well above what's previously been recorded, with the eventual goal of observing second sound at near-room temperatures.

Matthew D. Shoulders, associate professor of chemistry, does research at the intersection of chemistry and biology, illuminating the complex processes that help maintain the stability of proteins within cells. He is starting to develop new technology to actively control and direct the evolution of long stretches of DNA to help target mutations. Seed funding has also allowed Shoulders to secure external funding and explore the possibility of spinning off a company to pursue the commercial applications of this research.

Xueying Yu was previously the C. L. E Moore Instructor in Math and is now a postdoctoral scholar at the University of Washington. Yu's research looks at the behavior and solvability of what's called the nonlinear Schrödinger equation, which describes the path taken by light waves. Her seed funding led to several publications in peer-reviewed journals and facilitated fruitful collaborations between Yu and researchers at partner institutions.

Lucy mission launches to study ancient Trojan asteroids

Project scientist Professor Richard Binzel discusses NASA's latest interplanetary mission, which is co-led by Cathy Olkin '88, PhD '96

Sara Cody | Department of Aeronautics and Astronautics

Through imaging and spectral mapping, NASA's Lucy mission will give scientists the first close-up view of the topography and chemical composition of the Trojan asteroids, which could offer insights into the chemistry of the early solar system.
Image: Courtesy of Southwest Research Institute

In October, NASA's Lucy spacecraft launched from Cape Canaveral Air Force Station in Florida, beginning a 12-year, nearly 4-billion-mile mission to explore some of the oldest objects in the solar system. Named after the famous Australopithecus fossil, Lucy, the spacecraft will make two slingshot trips around Earth before heading toward a cluster of asteroids that share Jupiter's orbit, called the Trojan asteroids. These are believed to be nearly as old as the solar system itself.

Through imaging and spectral mapping, the spacecraft will give scientists the first close-up view of the topography and chemical composition of the Trojan asteroids, which could offer insights into the chemistry of the early solar system, how the planets formed, and the origin of the organic molecules that enable life.

Cathy Olkin '88, PhD '96 who received her bachelor's degree from the Department of Aeronautics and Astronautics (AeroAstro) and her doctorate degree from the Department of Earth, Atmospheric and Planetary Sciences (EAPS), is second-in-command as the deputy principal investigator on the mission. While she was busy preparing the spacecraft for launch, Project Scientist Richard Binzel, professor of planetary sciences in EAPS with a joint appointment in AeroAstro, described the goals of the Lucy mission.

Q: What are the roots of the Lucy mission? And how long has it taken to get to this moment?

A: The Lucy mission itself has been about a 5-year effort to go from the first proposal to the launch pad. But the story goes back many decades, trying to understand these objects out at the distance of Jupiter that we call the Trojan asteroids. They're asteroids that are stuck in a gravitational tug of war between the sun and Jupiter itself at what we call the Lagrange points, where the gravitational tug of the sun is equal to the gravitational tug of Jupiter. Once something falls into that zone, they're stable forever. So we think the Trojan asteroids are some of the earliest pieces of the formation of our solar system — we call them fossils of the solar system. And that's why we named the mission Lucy, after the Australopithecus fossil.

We think the Trojan asteroids date back to the very beginning of our solar system 4.56 billion years ago, which is older than any sample we can get from the Earth and any sample we've ever brought back from the moon. By studying the Trojan asteroids, we think we will be looking at some of the earliest pieces of the building blocks of planets.

Q: What are some of the outstanding questions that the Lucy mission expects to help answer?

A: We would like to know what the chemistry of the early solar system, particularly the organics, was like. Where did the organics, basically the carbon of life, come from? What was its earliest form? The Trojan asteroids are special because at Jupiter's distance most of the early chemistry is still literally frozen in time as it would have been at the beginning of our solar system. Their location further from the sun is colder than it is compared to the Earth, so essentially we think we are looking at pieces that have been frozen in time, not only in physical form but also chemically, since the very beginning.

For example, we think the earliest forms of water might be preserved in these objects. Once an object in space comes in close to the sun, about the Earth's distance, any water present begins to evaporate. But we think the Trojan asteroids have been cold enough that the original water they might contain is still there, frozen, intact, and ready for us to explore and evaluate.

Q: What will the spacecraft's life look like from launch until it completes its mission?

A: Lucy is on an amazing race track across the solar system to visit the Trojan asteroids.

About a year from now, it will swing by the Earth to pick up a little bit of velocity. And then it does another Earth swingby in late 2024. And that last swingby of the Earth will put it on a path out towards the Trojan asteroids. We have to build up speed and momentum to get that far away, so we use Earth's gravity to assist.

We will be out in the asteroid belt by 2025. First we will go by a small asteroid named Donald Johanson. Donald Johanson discovered the Lucy Australopithecus fossil, and when an MIT graduate student discovered this unnamed asteroid on our flight path, we were able to get it named after him.

Then, when we pass by Donald Johanson in the main belt, we will finally reach the Trojan asteroid six years from now, in August 2027. We are in one of the clouds of Trojan asteroids. These are in orbit, 60 degrees in front, and 60 degrees in the back of Jupiter. And we'll be in the leading group of Trojan asteroids, something we call the L4 Lagrange point, in 2027. We have two encounters in 2027, a third encounter in April 2028, and a fourth encounter in November 2028. And then in 2030, we swing back around the Earth, to go to the other side of Jupiter. We get to the cloud on the other side of Jupiter in 2033.

So, if you look at a map of the trajectory of the Lucy spacecraft, it is on a wild and crazy ride to get to both sides of Jupiter over the next 13 years or so.

Each of these objects is like a time capsule. And we'd like to see just how far back each time capsule is pushing our knowledge and understanding of how the Earth and planets came to be.

Q: How do you feel about this launch after so many years of studying the Trojan asteroids and preparing for this mission?

A: I started studying the Trojan asteroids myself back in the 1980s — in fact, the first paper I published on Trojan asteroids was with an Undergraduate Research Opportunity Program (UROP) student. It's almost surreal to think that we could go from seeing these objects as tiny points of light through a telescope to revealing them as real geological and geophysical worlds. And it takes decades. It takes a whole career to go from telescopic pinpoints to real, tangible objects. So in some ways, it's surreal. But in most ways, I am simply in awe of what this team has accomplished in a very challenging last few years.

A United Launch Alliance Atlas V rocket with the Lucy spacecraft aboard is seen in this 2 minute and 30 second exposure photograph as it launches from Space Launch Complex 41, on Oct. 16 at Cape Canaveral Space Force Station in Florida. Like the mission's namesake — the fossilized human ancestor, Lucy, whose skeleton provided unique insight into humanity's evolution — Lucy will revolutionize our knowledge of planetary origins and the formation of the solar system.
Photo: Bill Ingalls/NASA

SCHOOL OF SCIENCE
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A large stationary radio telescope in British Columbia, known as CHIME, for the Canadian Hydrogen Intensity Mapping Experiment, detects fast radio bursts (FRBs) — bright flashes of light with unknown origin, registering in the radio band of the electromagnetic spectrum. Scientists with the CHIME Collaboration, including Kiyoshi Masui and researchers at the MIT Kavli Institute for Astrophysics and Space Research, have assembled the telescope's first FRB catalog, which they presented at the 2021 American Astronomical Society Meeting. The new catalog is already yielding clues as to FRB properties; for instance, the newly discovered bursts appear to fall in two distinct classes: those that repeat, and those that don't.
Photo: Courtesy of CHIME