Science @ MIT

Winter 2021 **Published twice yearly**

red rover: mission to Mars

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Color has been added to highlight minerals in this image of Jezero Crater on Mars, the landing site for NASA's Mars 2020 mission. The green color represents minerals called carbonates, which are especially good at preserving fossilized life on Earth. On NASA's Mars 2020 mission, EAPS professor Tanja Bosak is the co-leader of a team of 14 Returned Sample scientists from the United States, Canada, and Europe. Image: NASA/JPL-Caltech/MSSS/JHU-APL/Purdue/USGS

SCHOOL OF SCIENCE
Massachusetts Institute of Technology

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Letter from the Dean

My fellow alumni and friends,

I write to you having taken up the mantle as dean just a scant four months ago in one of the most tumultuous times the Institute, the nation, and the world has seen. How lucky, then, that I have stepped into this role when the MIT School of Science is so well-positioned — with community members who can guide us, with scientific acumen and adherence to facts, through these times.

I owe a debt of gratitude to Michael Sipser, the Donner Professor of Mathematics, who has so ably led us here to this moment. Thank you, Mike, from me and from all of us here at MIT and beyond.

One of the most exciting parts of being dean is seeing the whole breadth of mind-blowing science being done by our brilliant and passionate faculty, staff, and students. It's also been wonderful to meet — albeit virtually — with you, the many friends and benefactors whose generosity enables the beautiful science we do.

Some of these are old friends, such as Curt Marble whose eponymous professorship I hold in astrophysics. Others, I am just getting to know, like Victor Menezes, who has created a challenge fund in the Department of Mathematics to support our recruitment and retention efforts. Read more about Victor and his wife Tara's philanthropic motivations on page 17.

Students and faculty alike have benefited from fellowships and professorships created in partnership with MathWorks. More than 100 student researchers from across MIT are supported by MathWorks fellowships, including brain and cognitive sciences graduate student Gurrein Madan and physics graduate student Nick Demos, who along with advisor, Professor Matthew Evans, the MIT MathWorks Professor of Physics, work within our LIGO research group to make our instruments even more sensitive to the detection of gravitational waves from distant astrophysical sources. Read more about these up-and-coming young scientists beginning on page 9.

Our cover story details the work of Tanja Bosak, a professor and geobiologist in the Department of Earth, Atmospheric and Planetary Sciences. Some of you might have gotten a chance to hear Tanja speak with her EAPS colleagues Professors Roger Summons and Ben Weiss at our virtual MIT Better World event in November. If you missed it, I encourage you to tune in to the recorded sessions on the Mars2020 mission, CRISPR, and other School of Science topics. (Details on where to watch are on the inside back cover).

This year, three of our faculty and one alumna received awards from the Breakthrough Prize Foundation for their early-career achievements in the fields of physics and mathematics. You can read more about each of their research areas beginning on page 19. Even as we celebrate the many achievements of our faculty and students, we also mark with a heavy heart the passing of a giant in the life sciences: our dear colleague Professor Angelika Amon. Angelika was the recipient of many awards — including the Breakthrough Prize — for her research that determined aneuploidy's effects on cells' ability to survive and proliferate. She was a valued colleague and dear friend to so many of us, and for me personally also a moral beacon.

Despite this loss, you can read in these pages that science at MIT is strong. But that doesn't mean it can't be strengthened — particularly when it comes to ensuring that we are recruiting the best and most diverse talent to address the challenges the world faces: the climate crisis, a global pandemic, rampant racial injustice and wealth inequality, and the continued attacks on the value of fundamental research.

At MIT, we have programs such as the Institute-wide Dr. Martin Luther King, Jr. Visiting Professor program that invites top talent, including Professor Thomas Searles, to the School of Science. Read more about Professor Searles on page 13. Within the school and our departments, we have fellowships supported by friends and benefactors who seek to ensure we are making space for underrepresented minorities in all the areas of science.

But we can always do better when it comes to diversity, equity, and inclusion. This work is vital to our mission to advance knowledge and educate students in science, technology, society, and other areas of scholarship that will best serve the nation and the world in the 21st century. Now, more than ever, we need the best scientists who will partner with engineers, educators, economists, thought leaders, policy makers, and sustainability advocates — making connections across MIT's schools and college to make a better world.

I can think of no better place and no better colleagues to work on these seemingly intractable problems. I hope you are as motivated as I am to continue reading about and supporting our scientific enterprise.

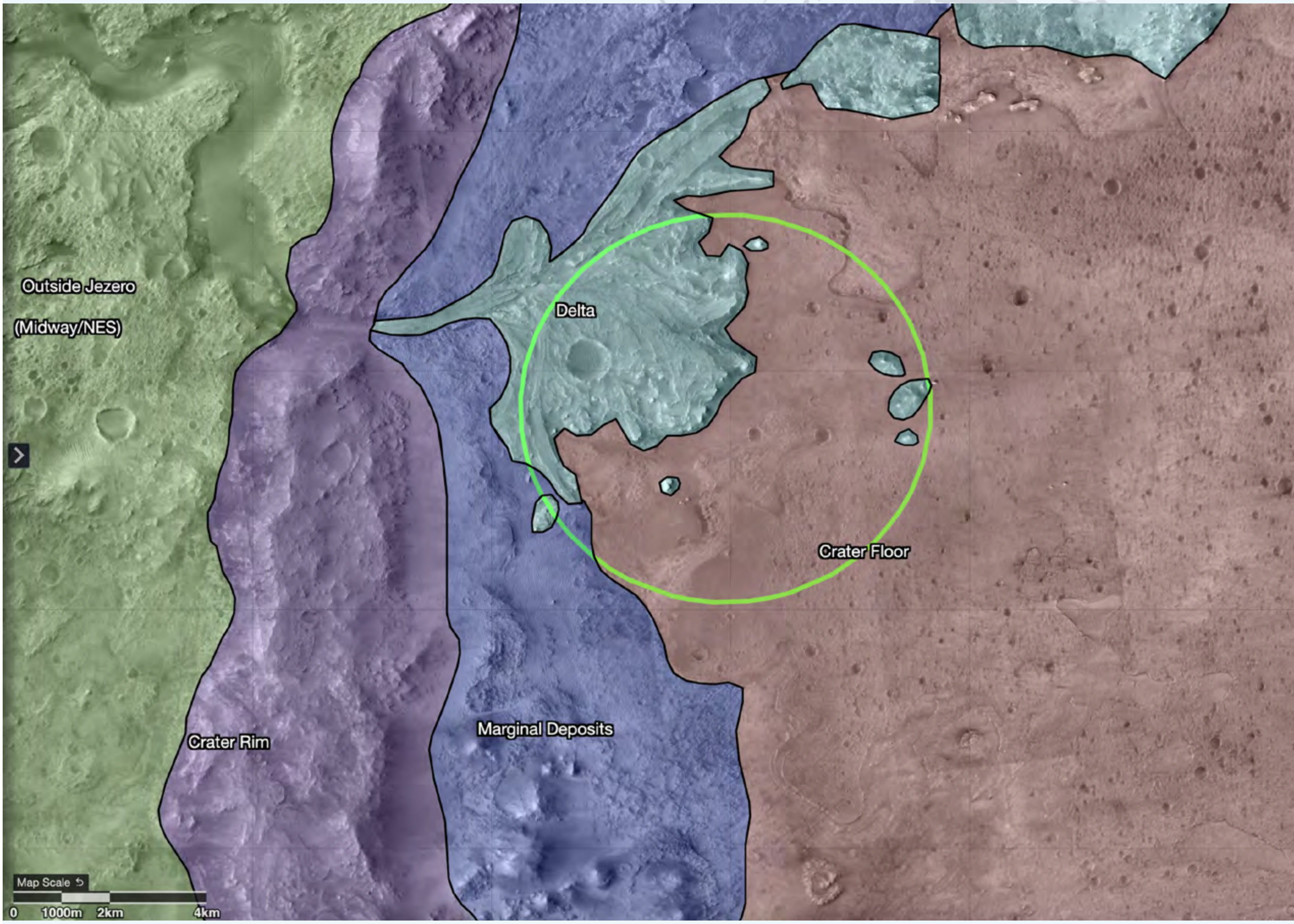
With my very best wishes,

Dean Nergis Mavalvala PhD '97

Field geology at a distance

As part of NASA's Mars 2020 mission, EAPS scientist Tanja Bosak helps determine the best samples to bring home from Mars

Laura Carter | School of Science



This map shows regions in and around Jezero Crater on Mars, the landing site of NASA's Perseverance rover. The green circle represents the rover's landing ellipse.
Photo: NASA/JPL-Caltech/USGS/University of Arizona

Life is shaped by the environment in which it lives. When looking at an organism today, that relationship can be easily observed. But when all you're left with is a fossil or rock, it can be tricky to identify the environment in which it formed, let alone the life forms that might have left their mark in that sample. Geobiologist Tanja Bosak now faces additional challenges as she searches for signs of early life on Mars.

"Mars is different. There are a lot of factors to consider. It's a great challenge. It's just fun to do; once we can do this for Earth, we can really set up the conditions for Mars."

Background: NASA

> “This gives us a window into the time when life may have been taking hold.”

Scientists first need to backtrack what Mars might have been like in the past and then what life might be expected in those conditions. This requires taking into account the different kinds of rocks and atmosphere seen on our neighboring planet today — and then estimating whether these aspects were the same billions of years ago. “It’s just a completely new, bigger direction,” she says.

A physicist during her undergraduate years in Croatia, Bosak was interested in big systems. After a brief stint as a meteorologist, she found the perfect field during her PhD at Caltech that combined her love for systems geology with biology’s intriguing variations in organisms and evolution. Now a geobiologist in the MIT Department of Earth, Atmospheric and Planetary Sciences, Bosak works to reveal processes that preserve microbial fossils and rocks made or shaped by microbes in the geologic record.

“We work to understand the chemical conditions under which microbes make certain minerals or fossilize in certain ways,” she explains, “because that helps us understand and reconstruct what the environment was like.” On Earth, for example, cyanobacteria are linked to a rise in oxygen in the atmosphere, which, in turn, altered ocean chemistry, and thus, affected the formation of marine minerals.

Mission to Mars

On NASA’s Mars 2020 mission, Bosak is the co-leader of a team of 14 Returned Sample scientists from the United States, Canada, and Europe. Once Perseverance, the newest martian rover, arrives at its final destination — a location that was chosen after extensive discussion in terms of both exploration and the logistics of landing — this group is charged with identifying the best samples to collect.

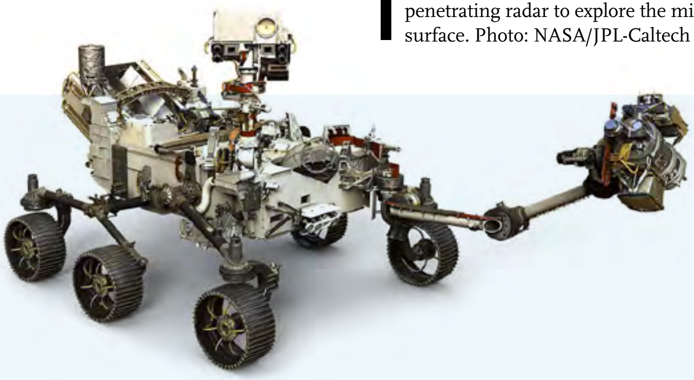
This is what sets this rover apart from its predecessors; its purpose is not to analyze. It is designed to sample and cache the rocks it encounters, ready for a subsequent mission to return them to Earth. Like the Apollo 11 mission, this is the first step in an attempt to bring a bit of our celestial neighbors to Earth.

Perseverance launched this summer and is expected to land in Jezero Crater in February 2021. Based on satellite imagery, Jezero Crater appears to be a dried lakebed. “We have a habitable environment — we have a lake. We have all the sediments that are known to preserve the signs of life on Earth,” says Bosak. The rover will examine the geologic remnants of a river delta with clay mineral deposits that might contain biosignatures, as well as an apparent shoreline where carbonate rocks, which are much more common on Earth, may have precipitated in the lapping lake water’s edge.

Remote roving research

The Perseverance rover is prepped for the mission’s four main science objectives: studying Mars’ geologic history, looking for signs of ancient life, collecting ideal samples for future research, and testing technologies for future use. Although the rover is armed with several instruments to carry out these objectives, there are a lot of complications to performing research on Mars.

On Earth, Bosak is used to bringing her notebook with her, sketching out the area she’s sampling and making notes, and then matching those notes to the samples that she bags. “When you get to the rock or outcrop, there’s a lot of orientation that happens, a lot of description that we do automatically,” Bosak explains. “But we won’t be able to



The Perseverance rover carries seven instruments, including ground-penetrating radar to explore the mineralogy and chemistry of the martian surface. Photo: NASA/JPL-Caltech

because there will be instruments that we actually have to call on to do that for us." The team must also determine how to document the samples. It's field geology with a twist.

Bosak will be monitoring the rover's traverse out of the crater, which is about 50 kilometers in diameter, deciding on the best and most diverse samples to collect. Emphasis is on the diversity. The scientists must ensure they have a wide array of material for analysis back on Earth.

And they must make their decisions quickly. "We'll have to move faster," she says. Unlike the Curiosity rover, which is still going strong well beyond its nominal mission, they will not have as much time to spend on details at any particular site.

During its prime mission, which is one Martian year — around two years on Earth — the team aims to choose 30 to 35 samples from Jezero Crater to bring back to Earth. Equipped with 43 sample tubes, the rover has the space to pick up a few extra samples from beyond the rim of the crater if it lasts longer than the prime mission. Bosak is hoping for the possibility that the rover can venture into this unexplored terrain.

A sample of the unknown

Despite the difficulties of remote field work on another planet, Bosak is excited. Unlike Earth, which suffers from the recycling of surficial materials by plate tectonics and weathering by an active water cycle, Jezero Crater, which is almost 4 billion years old, remains untouched by geologic activity.

"The surface of Mars is way older than anything that is preserved to such exquisite detail on Earth. This gives us a window into the time when life may have been taking hold," explains Bosak, "not just on Earth but on Mars too."

If no evidence for microbial life is found in a setting that has been known to foster life on Earth, scientists will have just as many questions to contemplate as they would with a positive identification. "We can't ever say there was no life, but with samples returned to Earth, we would be able to say whether, in this particular environment, there seemed to be any. If not, that's a puzzle," Bosak says.

Once the rover has cached all the samples and the team members have recorded the geology, it will be time to bring those pieces of Mars back to Earth for close inspection. A return mission is being planned by NASA to complete the intended round-trip project.

When asked if her research group might consider requesting small samples of the rocks she is helping to select once they have been brought back on Earth, she laughed. "That's 10 years from now." Though she has several potential analyses in mind, depending on the specific samples that are collected, a mission this complex requires focusing one step at a time. "Right now, we're making sure the best samples are collected." ○

Tanja Bosak, who studies the processes by which rock formations were produced in ancient environments, stands in front of some of the oldest stromatolites in the Pilbara region of western Australia during an astrobiology tour in 2013.
Photo: Courtesy of the researcher

A chemist who plays with space

Alison Wendlandt explores how the layout of atoms in molecules, such as sugars and drugs, can affect their nature and our bodies

Fernanda Ferreira | School of Science

Sliced rye bread.
Photo: Andrii Shablovskyi

Much of the earthy taste of rye bread is due to caraway seeds. These seeds get their flavor from carvone, a molecule made up of 10 carbon atoms, 14 hydrogen atoms, and one oxygen atom. But earthy isn't the only taste that exact collection of atoms can create. The minty taste of spearmint is also due to carvone. Which flavor you get depends on the spatial distribution of the atoms in the molecule; if you placed both carvones side by side, you'd see them as mirror images of each other.

The study of the spatial distribution of atoms in a molecule is called stereochemistry. Alison Wendlandt, the Green Career Development Assistant Professor of Chemistry at MIT, explains that when it comes to molecules, it's not only the atoms that determine molecular properties, but also the very three-dimensional arrangement of the similarly connected atoms.

This spatial distribution of atoms doesn't just impact flavor; it can also determine the effectiveness of a drug molecule. Wendlandt's work focuses on finding strategies for fine-tuning the stereochemistry of molecules and, in doing so, how quickly and thoroughly a drug treatment can work in patients.

Mirror images

When Wendlandt entered college, she wasn't planning on majoring in chemistry; she was a math major. "But I ended up taking organic chemistry, and it just clicked as a language," she says. Many students approach chemistry via memorization, but for Wendlandt the logic of chemistry innately made sense. "There was no memorizing, just understanding the rules," she remembers. "And then at that point, there was nothing else I could do."

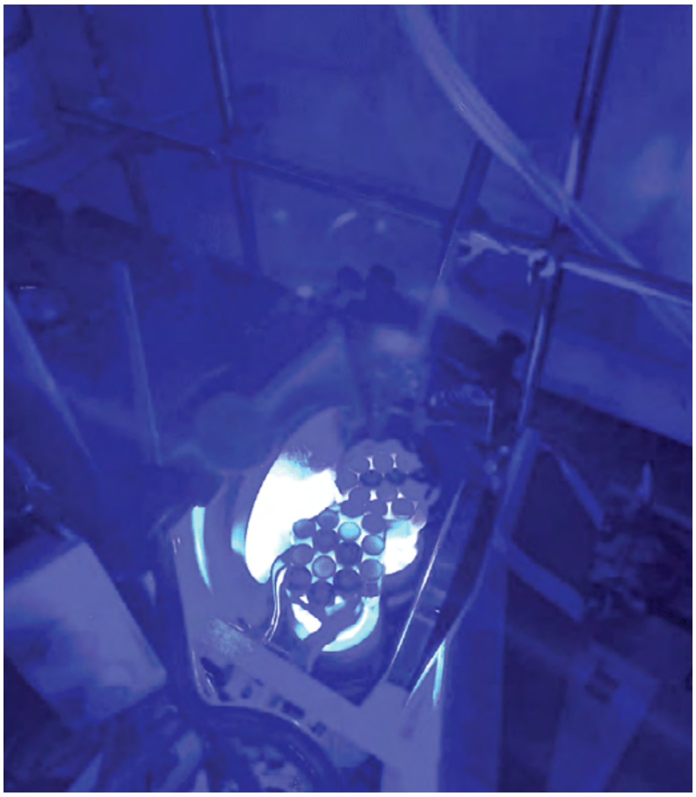
Wendlandt's training is in catalysis, which involves designing a catalyst to get a desired reaction. "A catalyst is any kind of reagent that can promote a reaction but isn't consumed in that reaction," says Wendlandt. This can be a reaction that is hard to perform, or one that leads to a specific product or outcome. During her postdoc at Harvard University, she focused on enantioselective catalysis, where a specific enantiomer, one of a pair of mirror-image molecules, is generated.

There are a number of aspects of enantioselective catalysis that attract Wendlandt to the work, but two stand out. "One is the importance of chiral drug molecules," she says. With drug molecules, it's often the case that only one enantiomer has the drug properties of interest, while the other has no effect or, in some cases, a negative effect. "There are some famous catastrophes where our failure to control or acknowledge the off-target effects of enantiomers led to disasters." Thalidomide, which was taken by pregnant women in the 1950s and 60s, is one such example. "One enantiomer was fine and treated morning sickness effectively, and the other enantiomer was a teratogen and led to birth defect issues," says Wendlandt. "It was totally a stereochemistry problem."

Wendlandt is also attracted to the molecular design aspect of the work. "It allows us to make a very small energetic change to reaction coordinates," she says. In terms of energy, Wendlandt explains, 1,000 to 2,000 calories — like the ones you consume and use for energy — can determine whether a product is a balanced mix of two enantiomers or whether it's a pure mix of just the one enantiomer of interest. With catalysis, Wendlandt says, you can actually control the reaction's path.

Sugar rush

Many molecules have stereochemistry, but the class of molecules Wendlandt is particularly interested in are sugars. She explains that, for molecules like amino acids and proteins, their properties are often determined by their functional groups — groupings of atoms on the molecule



Left: the intensity of the blue LED light that drives the reaction. There are about 28 reaction vials screening a variety of variables. Photo: Hayden Carder
Right: Alison Wendlandt. Photo: Justin Knight

that give it a specific nature. This is not the case with sugars. “Many of the biological and physical properties of sugars are stereochemistry-related,” Wendlandt says. With some important exceptions, all sugars are isomers, meaning they share the same basic chemical formula. “They just differ in terms of their spatial connectivity.”

In the body, sugars serve a number of functions, from energy and information storage to structure, and they’re also common components in pharmaceutical drugs. Some sugars, such as glucose and cellulose, are easy to come by, but others, particularly those that can be active ingredients in drugs, are harder to produce. These rare sugars “have to be made by chemical synthesis,” says Wendlandt.

Despite the importance of sugars, studying them is hampered by subpar methods for producing rare sugars, says Wendlandt. “And the reason these methods are poor has to do with our inability to manage issues of selectivity,” she says. Because the properties of sugars are determined by their stereochemistry, making a rare sugar often comes down to moving a specific atom from one location on the molecule to another. It’s a major challenge, but one Wendlandt is drawn to.

In a January 2020 paper in *Nature*, Wendlandt and her lab made allose, a rare sugar, by modifying the spatial distribution of atoms in a glucose molecule. The process involved breaking a chemical bond in one spot and reforming it in another spot on the molecule, which goes against a chemical principle called microscopic reversibility. “It dictates that the way the bond is broken is the same way that the bond is formed,” explains Wendlandt. To get around this, the lab decoupled the bond-breaking and bond-forming process by using two catalysts: one to break the bond and another to form it. With these two separate catalysts and some blue light to drive catalysis, a hydrogen atom is removed from a specific spot on the sugar molecule while a new hydrogen atom is added to another stereochemical position on that same molecule. With this switch, common glucose became rare allose.

Making allose is just the start. What drives the site selectivity of the reaction is not yet clear, and it’s a question Wendlandt and her lab are continuing to probe. “If we can understand why these reactions are selective, we can, in principle, design them to do other things,” says Wendlandt, such as breaking bonds at other sites on the molecule. Once predictability and stability are honed, this method can become a powerful tool in pharmaceuticals, including many FDA-approved antiviral, antibacterial, anti-cancer, and cardiac drugs. “A medicinal chemist can come in and say ‘OK, I want to edit this bond or that bond,’” imagines Wendlandt, letting them fine-tune sugars into potent pharmaceutical ingredients. This tinkering of atoms in a molecule can mean the difference between tragedy and safe, effective drugs. ○

Elegance in C. *elegans*

BCS graduate student and MathWorks fellow Gurrein Madan studies gut–brain signaling with implications for human health.

Alison Gold | School of Science

The naked eye can barely spot the transparent nematodes at the center of PhD student Gurrein Madan's neuroscience research. While *C. elegans* worms may initially seem an unassuming test subject for a graduate student who investigates the intricacies of gut–brain signaling, many of the genes found in *C. elegans* have counterparts in the human brain. Gurrein's research could yield new insights into the gut–brain relationship, which may have practical health implications for humans.

Gurrein works in the lab of Steven Flavell, the Lister Brothers Career Development Assistant Professor in the Picower Institute for Learning and Memory and Department of Brain and Cognitive Sciences. There, researchers address some of neuroscience's most essential questions using *C. elegans* as a model. The lab centers around understanding how neuromodulatory systems — such as those cellular systems that release, and are stimulated by, serotonin — affect animal behavior. The 1-mm long *C. elegans* are an ideal model for this work because their nervous system, with just 302 neurons, has been well-characterized: "It is the only animal on the planet where there is a full blueprint of how all of its brain cells are wired together," says Flavell. Combined with cutting-edge genetic and neural imaging technologies, the nematode model affords mechanistic studies of behavior from the scale of molecules to the whole brain.

> **"We are trained to expand the limits of what is known in our fields by being persistent."**

Gurrein was recently named one of this year's School of Science MathWorks fellows. The fellowship is a one-year renewable opportunity for graduate students in the School of Science who use the software MATLAB to make impressive strides in their research. Funding for the fellowship is provided with support from MathWorks, founded by its president John N. Little '78. MATLAB is used extensively by faculty, students, and researchers across the world — and MIT's campus — to develop algorithms, computations, and simulations.

Gurrein's project specifically looks at the neurons that line the *C. elegans* gut. These enteric neurons detect food and respond to changes in the animal's nutritional state while receiving feedback from other parts of the brain. Gurrein studies the class of neurons that release serotonin, which has a profound influence on the animal's feeding behavior.

"Currently, we are investigating what receptors expressed in these enteric neurons regulate the neurons' response to food as well as to feedback from the rest of the nervous system," Gurrein says. "By using genetics and neural imaging techniques, we attempt to uncover new molecular players involved in gut–brain signaling."

Dysregulation of gut–brain signaling has been linked to psychiatric and neurodevelopmental disorders, such as depression and autism spectrum disorder, in humans. Diverse molecules, including neurotransmitters and inflammatory molecules, mediate the two-way communication between the gut and the brain. However, the specific pathways behind this relationship are not well understood. Gurrein hopes to uncover more about the signaling mechanisms driving the connection.

"Much of our understanding of the fundamental pathways that control animal development and function comes from studies that originated in *C. elegans*, where basic genetic pathways were rapidly discovered," says Flavell. "Lo and behold, in humans, the same pathways control the same cellular processes. Many of these pathways have then become targets for drug development to treat human disease."

Using MATLAB at nearly every step of her research — from data collection and processing to analysis — Gurrein was an excellent candidate for the MathWorks fellowship. "I was excited to apply for two reasons. First, the fellowship was open to international students. Typically, international students are ineligible to apply to most fellowships out there. Second, MATLAB serves as the critical platform for comprehensively handling my data," Gurrein says.

Gurrein grew up in Amritsar in northwest India. Early in high school, Gurrein was placed in the sciences track, and upon graduation travelled to the United States for her undergraduate degree. During her sophomore year at Swarthmore College, she began research in a neurobiology lab and quickly realized how much she enjoyed the process of conducting scientific research. Moreover, she found the interdisciplinary nature of the neuroscience field exciting. After graduating with a BA in neuroscience in 2017, she immediately began her PhD at MIT.

"I really like the innovative aspect of a PhD," Gurrein says. "We are trained to expand the limits of what is known in our fields by being persistent, constantly troubleshooting, and coming up with new approaches to probe a question. I was initially considering medical school, but my research experiences led me to think that a PhD was probably a better fit for me."

Gurrein's colleagues noticed her enthusiasm for scientific discovery immediately. Flavell says she impressed him "right out of the gate." Within her first six months in the lab, Gurrein was instrumental in designing new experiments, conducting behavioral assays, and making notable discoveries that made their way into publications.

"Gurrein has an enormous amount of drive and energy, always trying her best to make impactful discoveries," says Flavell. "We have meetings once a week, and she always brings a critical eye to her own work, thinking about her data sets, what they mean, and how they give rise to new research directions. She wants to make sure the data she gets is really convincing and setting her on a path to making a true discovery."

"The general topic of how the gut is influencing the brain is a relatively new field," Gurrein says. "I think there is a lot of space for novel, exciting contributions." ○

Gurrein Madan. Photo: Steph Stevens

Path of least resistance

Physics graduate student and MathWorks fellow Nicholas Demos designs new mirror materials for better gravitational-wave detection

Kelso Harper | MIT Kavli Institute

Nicholas Demos, a physics graduate student, didn't travel a conventional path to MIT. A first-generation college student, Demos didn't have a clear trajectory in mind when he first attended California State University at Fullerton after high school. "It was kind of the path of least resistance," Demos says.

When his father passed away in the middle of his undergraduate studies, Demos left school to run the family business, Novatech Lighting Systems, which makes handheld spotlights. He ran the company for five years, but business didn't suit him, he says: "The pursuit of money wasn't motivating at all to me."

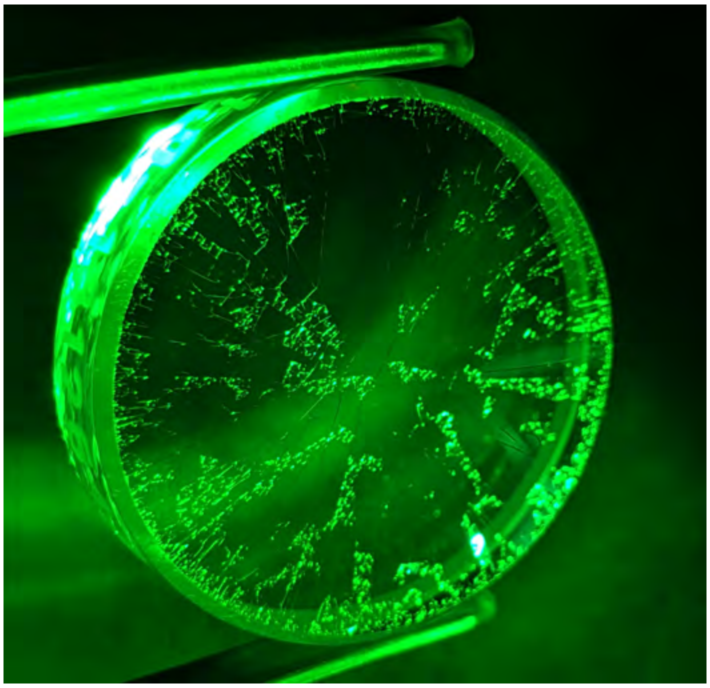
As soon as his brother graduated and could take over the business, Demos was ready to go back to school — this time with a clearer purpose. He chose to study physics, since he'd always excelled in math and science. Demos was the only student in his high school class to pass the AP calculus exam and even had what he calls a "side hustle" of building and selling computers out of his garage.

His renewed determination for academics paid off. After his first year back at CSU Fullerton, Demos' physics professor, Geoffrey Lovelace, asked him to join his lab. The following summer, Demos began researching gravitational waves, just as a more sensitive version of the Laser-Interferometer Gravitational Wave Observatory (LIGO) became operational.

"The detector was reaching a sensitivity where everyone thought it should work," says Demos, "Being on the cusp of a big discovery was exciting."

On Sept. 14, 2015, a little more than a year after Demos began his research, LIGO detected a gravitational wave for the very first time. It thrilled everyone in the small but growing field, including Demos. The ability to observe gravitational waves provides "a totally different way to look at the universe," says Demos. "It's a big step forward for astrophysics; there's potential for things we haven't even thought of appearing. A lot of unknown unknowns."

When Demos completed his undergraduate degree in 2017, he applied to MIT, hoping to continue working on LIGO. Matthew Evans, the MIT MathWorks Professor of Physics and Demos' current advisor, says he was immediately impressed with Demos' work. And according to Evans, Demos' old advisor told him, "Nick was the best undergraduate he'd ever had."



This mirror sample cracked during a process called annealing, where the sample is heated and allowed to slowly cool to reduce its thermal noise. While the mirror is transparent to visible light, it reflects 99.9995% of the infrared light that LIGO uses. Photo: Nicholas Demos

Demos measures mirrors

Whereas telescopes look for cosmic phenomena, LIGO listens. "LIGO is listening for the densest objects in the universe — neutron stars and black holes," Demos says. When these massive bodies near each other, they fall into a collapsing orbit, spinning faster and faster, closer and closer, until they collide.

"What LIGO detects is this chirp — this faster and faster, louder and louder signal — that is like the sound of spacetime vibrating," Demos says. These vibrations, or gravitational waves, travel vast distances through the universe, warping everything — stars, planets, people — in their path. What LIGO does is measure this stretching and

Nicholas Demos (left) shows a mirror-testing apparatus to Satoshi Tanioka, a visiting student from Sokendai University.
Photo: courtesy of the researchers

squeezing of spacetime. “It’s basically a big, 4-kilometer ruler,” Demos says.

To measure gravitational waves, a LIGO detector has dual 4-kilometer vacuum chambers laid in an enormous “L” shape. Scientists split a beam of light and send it to the end of each chamber, where it bounces off of highly reflective mirrors and returns to the corner of the “L.”

When a gravitational wave ripples through the Earth, it will stretch one arm of LIGO while squashing the other. The light, which has a fixed speed and won’t warp with the rest of the world, then takes a different length of time to travel down each arm. The scientists can measure this difference to detect the wave.

The challenge is that the ripples caused by gravitational waves are minuscule since, despite appearances, gravity is a very weak force. In terms of the squashing and stretching, “we’re talking about these tiny, fractional changes,” says Demos, “roughly one-thousandth the size of a proton.”

This means that everything in the LIGO experiment must be extremely precise and very still. Otherwise, the gravitational wave signals will be lost in a sea of noise. Unfortunately, some sources of noise are harder to eliminate than others. “The surface of the mirror is made up of atoms, and these atoms are jiggling about,” Demos says. “If you’re trying to measure something that’s smaller than a proton, that’s a problem, because your ruler is jiggling about on both ends.” The noise from the movement of atoms, also called thermal noise, is nearly unavoidable — the motion only stops at the unreachable temperature of absolute zero. However, some materials have less of this thermal noise than others.

Demos’ job is to design and test new mirror materials to find those with the lowest thermal noise. In fact, he is one of the few people in the world able to test these samples. Matthew Evans and Research Scientist Slawomir Gras have developed the only apparatus able to quickly test full mirror samples, as opposed to just a single layer or a few layers of the materials used to coat the mirrors.

“Any coating that LIGO wants to use will first be characterized by our experiment,” Demos says.
The Evans lab is in the process of upgrading their setup to measure thermal noise across the surface of a sample, as opposed to only at a single point.

“This is a job which is really at the heart of progress in gravitational wave detection,” Evans adds. “Nick’s persistent determination to get things done has really made a big difference for us.”

Demos makes math work with MATLAB

In September, Demos was one of a select group of students in the School of Science to receive a $70,000 fellowship from MathWorks, a software company that produces mathematical computing programs like MATLAB and Simulink.

“The MathWorks fellowship is a big honor,” says Demos, “It’s a huge relief financially because I don’t have to worry, my lab doesn’t have to worry, and I’ll be able to really pursue this.”

It’s particularly appropriate for Demos to win this fellowship, as he frequently uses MATLAB in his research. “He’s gone through all of our analysis software in MATLAB and really refactored that code from the ground up,” says Evans. He adds that Demos is very deserving of this award, but he’s not worried about the recognition going to Demos’ head.

“There’s a certain humility in his approach to things, which is not something you always find.”

For Thomas Searles, a passion for people and science at HBCUs and MIT

Physicist and Martin Luther King Jr. Scholar examines the optical properties of semimetals

Alison Gold | School of Science

When Thomas Searles was assigned a book report in the first grade, he initially had trouble choosing a topic. He really didn't like fiction books. After a bit of indecision, he chose to write his report on a book about Black astronauts. Though he didn't realize it at the time, his journey to becoming a physicist at MIT had just begun.

"I looked in the book, and there was Ronald E. McNair, who happens to be an MIT alum, randomly; he got his PhD here," says Searles. "And it said that he was a laser physicist. So, I said, 'Well, that's what I'm going to be, because I want to be an astronaut.'"

Searles is now a member of the 2020–2021 Martin Luther King Jr. (MLK) Visiting Professors and Scholars Program cohort at MIT. Since 1995, the MLK Scholars Program has brought in a total of 67 visiting professors and 21 visiting scholars from across all academic disciplines. Individuals of any underrepresented minority group are eligible to apply, and scholars are selected for their contributions both to their fields and their potential contributions to MIT.

"It's something that was always on my radar as a young Black scientist," says Searles. "It was something that was on my 5- to 10-year plan."

Searles is currently an associate professor in the Department of Physics at Howard University, a historically Black college and university (HBCU) located in Washington, D.C. There, he established a new research program in applied and materials physics. He is also the director of a new academic partnership between IBM and 13 other HBCUs called the IBM-HBCU Quantum Center.

Searles' research career began as an undergraduate in mathematics and physics at Morehouse College, an HBCU in Atlanta. Before graduating in 2005, he worked in an optics lab, examining the properties of light and its interactions with matter.

"A lot of us had an interest in optics, because that was the only experimental lab that we had at Morehouse at the time," says Searles. "So naturally, I applied to graduate schools that were optics related."

That interest led him to pursue his PhD in applied physics in the Department of Electrical and Computer Engineering at Rice University in Houston, Texas, from which he graduated. Before graduating in 2011, he studied light-matter interactions, and completed a thesis about the magneto-optical properties of carbon nanotubes, which are cylinders composed of a single layer of carbon molecules. Carbon nanotubes are extremely strong, light-weight, conductive molecules, making them promising for a variety of mechanical applications.

In 2015, Searles started at Howard University. "I wanted to go back and work at an HBCU. I thought of my experience working in the Morehouse optics lab and how they kind of shaped my experience," says Searles. "So then I was like, 'What can I do that's different from everyone else that will also provide opportunities to a lot of Black students?' So, I set out to start a terahertz experimental lab, knowing that it was going to be difficult. And it was difficult. But we were able to do it."

In the terahertz spectroscopy lab at Howard University, researchers work with matter that has a large wavelength and a frequency between several hundred gigahertz and several terahertz. During the first so-called quantum age in the mid-1900s, silicon was the new, exciting material used to develop transistors. Now, researchers in fields like chemistry and physics are on the hunt for the next material to be a platform for a new generation of quantum technologies.

Thomas Searles. Photo: courtesy of the researcher

“The primary goal is to study materials for new computers, making them either safer, faster, or more secure,” says Searles. “This whole idea of quantum computing is what we’re focusing our lab on, moving toward this idea of ‘quantum advantage.’”

Quantum computing relies upon the use of quantum materials — which have unique electronic and magnetic properties — to build faster, stronger, and more powerful computers. Such machines are likely to provide this “quantum advantage” for new developments in medicine, science, finance, chemistry, and many other fields.

In 2016, Searles met MIT associate professor of physics and Mitsui Career Development Professor in Contemporary Technology Joseph Checkelsky at an event through the National Science Foundation Center for Integrated Quantum Materials.

“The idea was to try to find people that we wanted to collaborate and work with,” Checkelsky said. “And I think I even wrote down in my notepad Thomas’s name and put a big underline that I should work with this guy.” Searles says the best thing that can ever happen to a spectroscopist like himself is to find “a crystal growth person that provides samples, who you also really vibe with and like as a person. And that person for me has been Joe.” The two have been collaborating ever since.

Checkelsky’s lab works to discover new crystalline materials that enable quantum phenomena. For instance, one material that has previously been of interest to Checkelsky is a kagome crystal lattice, a 2D arrangement of iron and tin molecules. Both Checkelsky and Searles are interested in applying a branch of mathematics called topology to solids, particularly semi-metals.

“One of the roles Thomas plays is to examine the optical properties of these new systems to understand how light interacts with quantum materials,” says Checkelsky. “It’s not only fundamentally important, it can also be the bridge that connects to new technologies that interfaces light with quantum science.”

Searles’ expertise on the optics side of the research enables him to identify which materials are ideal for further study, while Checkelsky’s group is able to synthesize materials with certain properties of interest.

“It’s a cycle of innovation where his lab knows how it can be tested and my lab knows how to generate the material,” says Checkelsky. “Each time we get through the cycle is another step toward answering questions in fundamental science that can also bring us to new platforms for quantum technology.”

> “What can I do that’s different from everyone else that will also provide opportunities to a lot of Black students?”

Checkelsky nominated Searles for the MLK Scholars Program in hopes of further expanding their academic partnership. He now serves as Searles’ host researcher through the program.

“I hope to extend my collaboration with Joe to not only [explore] this condensed matter, experimental side of my group, but to expand this into Lincoln Laboratory and the quantum information portion that MIT has,” says Searles. “I think that’s critical, research-wise.”

In addition to their research goals, Searles and Checkelsky are excited to strengthen the general connection between MIT and Howard.

“I think there are opportunities for Thomas to see, for example, the graduate school process in our department,” says Checkelsky. “Along the same lines, it is a great opportunity for MIT and our department to learn more how to connect to the people and science within HBCUs. It is a great chance for information to flow both ways.”

Searles also hopes to encourage more HBCU students to pursue graduate study at MIT. “The goal of increasing the number of qualified applicants [from HBCUs] — I think that’s something that I can measure metrically from the first year,” says Searles. “And if there’s anything that I can do to help with that number, I think that would be awesome.”

Although Searles is working remotely from Washington, D.C. due to the Covid-19 pandemic, he has already found a home — albeit a virtual one — at MIT. “I’ve been welcomed by the MIT Physics Department,” says Searles. “They’ve really involved me.” ○

Big questions in chemistry

Amanuella Mengiste, a chemistry graduate student and 2020–2021 Robert J. Silbey fellow, explores the ever-expanding field of directed evolution

Liz McGrath | Chemistry

Amanuella Mengiste. Photo: Steph Stevens

“MIT really is the place to be if you want to do cool, interdisciplinary, on-the-cutting-edge science, particularly in biological engineering, chemical biology, and biology. I knew my training would be top-notch,” says Amanuella Mengiste, a third-year graduate student in the lab of chemistry professor Matthew Shoulders. She was selected as the inaugural recipient of the prestigious Robert J. Silbey fellowship for the fall 2020 semester.

Robert J. Silbey, who passed away in 2011, joined the MIT Department of Chemistry faculty in 1966 and became head of the department in 1990, then director of the Center for Materials Science and Engineering in 1998. He later served as the dean of Science from 2000 to 2007. Silbey was renowned for his leadership and political acumen as dean, his commitment to enhancing MIT’s education and research, and his work in condensed phase theory and quantum biology — fields that he helped to pioneer. The Robert J. Silbey fellowship was created in his memory to support young women in chemistry.

Mengiste grew up in Addis Ababa, Ethiopa, and attended the equivalent of a U.S. charter school for all her pre-college schooling. Because the school did not offer any advanced classes and had no working teaching laboratories, Mengiste’s initial access to experimental science was very limited.

From an early age, Mengiste was a curious and bookish child, and her parents embraced this attribute. “They never hesitated to buy the books I wanted,” she remembers. “My dad, who was a civil engineer with an innate curiosity himself, would spend hours gazing at the stars with me because I initially aspired to be an astronaut.”

One of Mengiste’s favorite childhood memories is the time she and her father spent preparing for her first school science fair. He had focused on renewable energy and green agriculture in his career; so they built a model of a wind turbine for wind-powered energy generation. “That was my first hands-on experience with science and engineering, and I guess I never looked back,” she reflects.

“I truly believe I won the lottery with my wonderful parents,” she says. “Together they nurtured me and my younger brother until my father unfortunately passed away when I was 13. My widowed mother then continued to raise me and my brother as a single parent. And if I may say so myself, she’s done an incredible job.”

While liberal arts institutions in the United States emphasize academic exploration, the higher education system in Ethiopia encourages specialization. In their last year of high school, students take a national exam and, depending on their results, get channeled into a select few

> “MIT really is the place to be if you want to do cool, interdisciplinary, on-the-cutting-edge science.”

careers. This had caused Mengiste’s parents to worry that their daughter would not be able to fulfill her academic aspirations in Ethiopia.

“One night, I remember, when I was 12, my dad made a list of U.S. universities that he thought might be a good fit for me.” As he considered each option, he put a strike through the name, until one remained. “Princeton will be the perfect fit for you!” he declared. Years later, in her senior year, Mengiste applied to a number of schools, including her father’s first choice. “I got into Princeton, and that changed my life,” she says.

When Mengiste arrived at Princeton in 2014, she quickly discovered her passion for experimental science and research while working in the lab of Professor Abigail Doyle, an organic chemist whose lab specializes in the development of new catalytic methods. There, Mengiste developed a new reductive cross-coupling reaction that allows nickel-mediated, photo-assisted coupling of aliphatic aziridines and aryl halides. She also expanded the lab’s previously reported methodology to include the photo-assisted cross-coupling of styrenyl azirdines with aryl halides.

In the fall of 2018, after graduating with high honors with her bachelor of science in engineering, Mengiste headed to MIT to pursue a PhD in chemistry.

Her work up until that time was in hard-core synthetic methodology, but when she arrived on MIT’s campus, she switched gears and joined Professor Matthew Shoulders’ biological chemistry group. “Part of my course work at Princeton was in the realm of biological engineering, biochemistry, and chemical biology,” she explains, “and I found that the big questions researchers were asking in those fields suited my intellectual interests perfectly.”

Mengiste has been working on two projects in the Shoulders’ group, both in the ever-expanding field of directed evolution. The first project aims to expand on a method the laboratory developed to cause targeted mutations in *E. coli*. Specifically, she and her lab colleagues are working to expand the mutagenic ability of the lab’s previously reported tool.

Mengiste’s second project focuses on using mPACE, a platform that allows researchers to evolve mammalian proteins directly within mammalian cellular environments. She is particularly interested in evolving a class of proteins known as G protein-coupled receptors (GPCRs). GPCRs are the conduits by which cells detect external stimuli — be they photons, small molecules, or proteins. Members of this large protein family exist at the interface between extracellular and intracellular environments and are the bedrock on which much of cell signaling is based. As such, there is immense interest in understanding, co-opting, and controlling GPCRs and the signal transduction pathways they modulate.

Mengiste’s long-term goal is to develop and implement highly adaptable GPCR-specific strategies to create GPCRs that are constitutively active — that is, activated by pharmacologically inert small molecules and capable of activating different signaling pathways in a controlled manner.

Mengiste cares deeply about education, as did Professor Silbey. Her first experience with teaching was in high school when she volunteered as a math and english tutor for three years. At Princeton, she became a peer tutor at the McGraw Center for Teaching and Learning and served as a peer academic advisor for her residential college. “At MIT, I was really excited to TA for 5.111,” she says of the General Institute Requirement course. “It was truly rewarding to work with such bright, hardworking students, and I still keep in touch with a number of them!”

In her limited spare time, Mengiste’s favorite pastime is reading. She participates in a monthly literary and arts bookclub collective that focuses on reading works and engaging with art by Ethiopian and Eritrean authors and artists, which she says has been an amazing experience.

Mengiste also cares deeply about community service. Her most meaningful engagement at MIT was with the MIT Summer Research Program (MSRP) where, for two summers, she served as a pod leader — a mentor for students from underrepresented backgrounds conducting summer research at MIT. “I remember how intense it had been for me starting out in the Doyle lab,” she remarks, “and I wanted to make sure that I could support students who were going through similar life-changing experiences at MIT.” One of her current roommates is a mentee of hers from MSRP 2019. “The bonds formed over that summer program are really special,” she says, “and last a lifetime.” ○

A small way of saying thank you

Victor Menezes, SM ’72, founds Challenge Fund in Mathematics

Danielle Ford | Physics

Tara and Victor Menezes. Photo: courtesy of the donors

“It might not change the world, but it does try to light a small candle.”

These are modest words from Victor Menezes SM ’72, a Course 15 alumnus who recently created the Victor J. Menezes (1972) Challenge Fund in Mathematics. These words reflect the heart of many in the School of Science community where an act of “lighting a small candle” often leads to creativity and exploration that may one day in fact change the world. The Menezes Challenge Fund in Mathematics will support the department’s outreach programs and create challenge opportunities for students from underrepresented backgrounds and underserved communities in the United States and elsewhere to support their goals of attending MIT and other top-ranked universities.

Victor Menezes was born and raised in India. After receiving his undergraduate degree in electrical engineering from the Indian Institute of Technology at Bombay, he traveled abroad for the first time.

On that trip, the first of his many around the world, he joined the masters of science program at the MIT Sloan School of Management (Course 15) with a focus on finance and economics. MIT in the 1970s was an evolving and exciting place to be; Professor Paul Samuelson had just won the Nobel Prize in economics; Professor Robert Merton had just started teaching; and Menezes enrolled in his first course in finance and options theory.

“There were quantitative luminaries and future Nobel Prize winners all around us,” says Menezes, who was thrilled to be a part of that community, harboring a belief that mathematics underpins finance, economics, and electrical engineering. It allowed him to flourish in his career.

After completing his SM in 1972, Menezes joined Citibank where he worked for 33 years, living with his wife Tara and their four children all over the world — India, New York, Manila, Hong Kong, Brussels, and finally New York again, where they reside for their retirement.

Menezes remained a close part of the MIT community throughout his career and is a Life Member of the MIT Corporation. When asked about his motivation for the creation of the Menezes Challenge Fund in Mathematics, he stated, “Mathematics was the bridge in my life. Math is the Latin that binds the modern world. I heard about the Math Department’s outreach programs, MathROOTS and PRIMES Circle, and it struck a chord. I thought they were wonderful. They encourage math development at the high school level in the United States and elsewhere when the support is most needed!”

Victor and Tara Menezes are grateful for the knowledge and friendships gained through MIT and are happy to offer their support. “Philanthropy is a very big word. Our support is a small way of saying thank you.”

Tea time with Champions of the Brain Fellows

Rachel Donahue | Brain and Cognitive Sciences

The afternoon tea kit of tea bags, cookies, and chocolate mailed to attendees of the Champions of the Brain Fellows event, which was held virtually this year. Photo: Steph Stevens

On October 21, the Department of Brain and Cognitive Sciences (BCS) held its seventh annual Champions of the Brain Fellows reception — this time, virtually. Guests received packages of tea, cookies, and chocolates prior to the event — because what is tea without chocolate? — and in that way shared a small physical token of the annual event, even at a distance.

The celebration provides an opportunity for fellows to meet and thank the friends and alumni who make it possible for them to explore their scientific pursuits and for our donors to learn firsthand about the research their support enables.

The evening was hosted on Zoom by Al ’51 and Barrie Zesiger, founding Champions of the Brain Fellows. Over the years, the Zesigers have helped to endow multiple fellowships in the department, and they have enjoyed meeting and keeping in contact with many of their former fellows.

Department head James DiCarlo thanked the guests, faculty, and graduate students for joining the virtual celebration and commended the students for their perseverance and ingenuity during research shutdowns. “You have found innovative ways to continue the research and maintain the vibrancy of our community throughout the new challenges we have faced,” said DiCarlo.

This year, attendees heard from five current students who gave 3-minute “lightning talks” followed by a question and answer session. Afterward, the guests were put into small groups for ice breakers and two rounds of MIT BCS Brain Teasers.

Do you know the name of the scientist who founded the Department of Brain and Cognitive Sciences (then known as the Department of Psychology) in 1964? Today, many people know that BCS is Course 9, but what field of study was Course 9 originally? Do you know what was unique about Patient H. M., an individual studied by the late BCS Professor Suzanne Corkin? The winning team, Amygdala, knew the answers.

One of the benefits of hosting the celebration virtually was how many supporters could join, logging in from all across the country.

Dean of the School of Science, Nergis Mavalvala, gave closing remarks “I was a graduate student in Building 20, and have many fond memories,” said Mavalvala, who is also the Curtis and Kathleen Marble Professor of Astrophysics. “As a physicist, I find that the complexities of matter and forces are actually much simpler than the brain,” she joked.

For information on joining the Champions of the Brain Fellows, or to make a gift in support of the department, contact Rachel Donahue at 617-715-2898 or rjd@mit.edu.

The answers to the above brain teasers: Hans-Lukas Teuber founded BCS as the Department of Psychology in 1964; Course 9 was originally General Study; and Patient H. M. had anterograde amnesia, which means he could not form new memories though his long-term memories remained intact.

Breakthroughs in math and physics

2021 New Horizons in Physics and New Frontiers in Mathematics prizes

Jennifer Chu | MIT News Office

Physicists Tracy Slatyer and Netta Engelhardt and mathematicians Lisa Piccirillo and Nina Holden PhD '18 were honored by the Breakthrough Prize Foundation.

Three MIT faculty members and one alumna were named winners of prizes awarded by the Breakthrough Prize Foundation, which honor early-career achievements in the fields of physics and mathematics.

Tracy Slatyer and Netta Engelhardt received the 2021 New Horizons in Physics Prize, an award of $100,000 that recognizes promising junior researchers who have produced important work in their field.

Lisa Piccirillo and Nina Holden will each receive the 2021 Maryam Mirzakhani New Frontiers Prize, a $50,000 award that recognizes outstanding early-career women in mathematics. The prize was created in 2019 in honor of Iranian mathematician and Fields Medalist Maryam Mirzakhani, who made groundbreaking contributions to her field before her death in 2017 at the age of 40 after battling breast cancer.

"The New Horizons and New Frontiers prizes recognize some of the most talented young researchers in the world," says Nergis Mavalvala, dean of MIT's School of Science and Curtis and Kathleen Marble Professor of Astrophysics. "I'm thrilled that four colleagues from MIT have been recognized as amazing researchers who have already done important and impactful work. I can't wait to see what comes next from these brilliant young women."

Both prizes are part of a family of awards given out each year by the Breakthrough Prize Foundation and its founding sponsors — Sergey Brin, Priscilla Chan and Mark Zuckerberg, Ma Huateng, Yuri and Julia Milner, and Anne Wojcicki. The winners are chosen by a committee of past awardees in each field.

Dark matter patterns

Tracy Slatyer is the Jerrold R. Zacharias Career Development Associate Professor of Physics at MIT, and received the 2021 New Horizons in Physics Prize "for major contributions to particle astrophysics, from models of dark matter to the discovery of the 'Fermi bubbles,'" according to the award citation.

> "[These] prizes recognize some of the most talented young researchers in the world."

Tracy Slatyer.

Netta Engelhardt.

A theoretical physicist who works on particle physics, cosmology, and astrophysics, Slatyer has pioneered new techniques to search through telescope data for clues to the nature and interactions of dark matter, which is thought to make up more than 80 percent of the matter in the universe. She has used data from the Fermi Gamma-Ray Space Telescope to co-discover the Fermi bubbles, a mysterious structure of high-energy gamma rays bubbling out from the center of the Milky Way galaxy.

Slatyer grew up in Canberra, Australia, and received her undergraduate degree from the Australian National University. She carried out postgraduate research at the University of Melbourne before moving to Boston in 2006 as a graduate student at Harvard University. She worked as a postdoc at the Institute for Advanced Study in Princeton, New Jersey, for three years before joining the MIT faculty as a member of the Center for Theoretical Physics in 2013. She is the recipient of the Henry Primakoff Award for Early-Career Particle Physics and a Presidential Early Career Award for Scientists and Engineers.

Black hole information

Netta Engelhardt is an assistant professor of physics and a member of the Center for Theoretical Physics at MIT. She shares the 2021 New Horizons in Physics Prize with three others: Ahmed Almheiri of the Institute for Advanced Study, Henry Maxfield of the University of California at Santa Barbara, and Geoff Penington of Stanford University. The prize recognizes the researchers “for calculating the quantum information content of a black hole and its radiation.”

Black holes are thought to contain a huge amount of information in the form of the matter that falls into them. They are also known to emit radiation in response to quantum jiggling of their surroundings. To what extent information is released along with this radiation has been a conflicting question for both quantum mechanics and Einstein’s theory of gravity.

Engelhardt, Almheiri, and Maxfield found that as matter falls into the black hole, the information that it contains increases. As the black hole ages, it gives off radiation and in the process spews information back out. Penington came to the same conclusion independently. Together, the researchers’ work showed that information can indeed safely escape a black hole.

Engelhardt’s research focuses on gravitational aspects of quantum gravity, and on understanding the predictions of quantum gravity in the context of gravitational singularities — locations in space-time where the gravitational field of an astrophysical object is predicted to be infinite. She is investigating the black hole information paradox, thermodynamic behavior of black holes, and the idea that singularities are always hidden behind event horizons.

Engelhardt grew up in Jerusalem and Boston. She received her undergraduate degree from Brandeis University and her PhD from the University of California at Santa Barbara. She was a postdoc at Princeton University and a member of the Princeton Gravity Initiative before joining the MIT physics faculty in July 2019.

> “I can’t wait to see what comes next from these brilliant young women.”

A tangled proof

Lisa Piccirillo is an assistant professor of mathematics at MIT. She is being awarded the 2021 Maryam Mirzakhani New Frontiers Prize "for resolving the classic problem that the Conway knot is not smoothly slice," according to the award citation.

For decades, the Conway knot was an unsolved problem in the subfield of mathematics known as knot theory. One of the fundamental questions that knot theorists try to puzzle out is whether a knot is a "slice" of a more complicated, higher-order knot. Mathematicians have determined the "sliceness" of thousands of knots with 12 or fewer crossings, except for one: the Conway knot. Named after the mathematician John Horton Conway, this knot consists of 11 crossings, the sliceness of which mathematicians had struggled for decades to explain.

Piccirillo heard about the Conway knot problem as a graduate student at the University of Texas at Austin. Over one short week in the summer of 2018, she solved the puzzle, with a proof that showed the tricky knot was in fact not a slice of a higher-order knot. Her work, and the classical tools she used to lay out her proof, were published earlier this year — a feat that generated widespread interest beyond the mathematics community.

Piccirillo was raised in Greenwood, Maine, and earned an undergraduate degree from Boston College. She earned a PhD in low-dimensional topology at the University of Texas at Austin and worked as a postdoc at Brandeis University before joining the MIT faculty in July 2020.

Random triangulations

Nina Holden PhD '18 is a junior fellow at the Institute for Theoretical Studies at ETH Zurich, and an alumna who earned a doctorate in mathematics from MIT in 2018.

Nina Holden PhD '18.

Lisa Piccirillo.

She is a recipient of the 2021 Maryam Mirzakhani New Frontiers Prize "for work in random geometry, particularly on Liouville quantum gravity as a scaling limit of random triangulations."

Holden's research focuses on probability theory, and in particular, conformally invariant probability. She studies universal models for random surfaces, which are of interest in mathematical physics and theoretical probability.

A classical result in probability theory is that a random walk converges to the continuum random process known as Brownian motion when the lattice size is sent to zero. Holden has proved similar convergence results for discrete random surfaces known as random planar maps. In particular, she proved in joint work with Xin Sun that certain random planar maps known as triangulations converge to the continuum random surfaces known as Liouville quantum gravity surfaces. This confirms predictions made in string theory and conformal field theory in the 1980s, and is also of fundamental interest in theoretical probability theory.

Holden earned her bachelor's and master's degrees in mathematics from the University of Oslo before pursuing a PhD in mathematics at MIT, where she studied with Scott Sheffield, the Leighton Family Professor of Mathematics. She will be an associate professor at the Courant Institute of Mathematical Sciences at New York University in 2021.

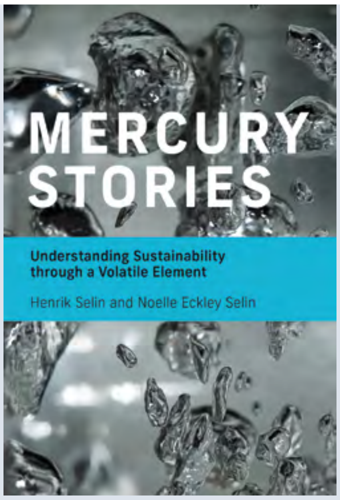
All images courtesy of the researchers.

Books from Science

Bringing down mercury

Noelle Eckley Selin explores toxin’s history, works to change policy

Ari Daniel PhD ’08 | MIT Alumni Association



Back before the world turned upside down, before COVID-19 gripped the globe and our bodies, back when you could easily take an airplane to a remote destination for vacation, Noelle Selin did just that.

This past New Year’s Eve, Selin and her husband, Henrik, touched down in southern Spain. They visited the cathedral in the heart of Seville, ate an entire ham-themed dinner, and admired the orange trees of Córdoba. They also rented a car to drive the couple hours north to the small town of Almadén. They were drawn by a tour of the mercury mine there. It closed in 2002 after operating for millennia, producing close to a quarter-million metric tons of mercury and poisoning the people who worked there, many of them convicts, slaves, and prisoners of war.

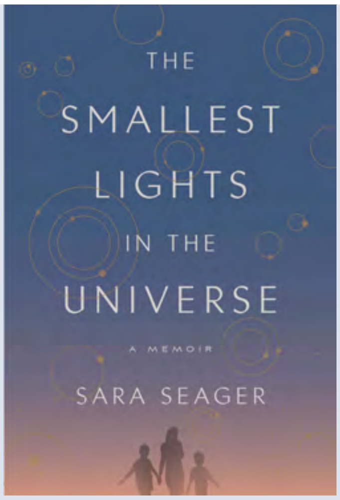
Selin, an associate professor in the MIT Institute for Data, Systems, and Society and the Department of Earth, Atmospheric and Planetary Sciences, studies pollution, from emission to its environmental and health impacts to ensuing policy responses. Much of her work focuses on mercury, but she also examines ozone and other particulate matter. Her book, *Mercury Stories*, now available from MIT Press, was co-authored with Henrik, who is an associate professor of international relations at Boston University. It’s no wonder the two of them would make an excursion to Almadén, don hard hats, and ride a little elevator deep into the Earth. “When we plan trips,” Selin says, “going to a mercury mine seems like a really cool thing to do on vacation.”

Read more of this article at *MIT Spectrum*.

Finding light in the dark

Sara Seager’s research into the stars and beyond revitalizes her after a traumatizing loss

Laura Carter | School of Science



A renowned astrophysicist, Sara Seager has found more than scientific discoveries in her research into deep space — she has also found solace.

After the death of her husband, Seager was left to raise her two sons, manage her house, and delve into her career as a planetary scientist. Feeling alone on Earth, she turned her gaze upward to explore what else might be out there.

In her new memoir *The Smallest Lights in the Universe*, published by Crown, Seager, a professor in MIT’s departments of Earth, Atmospheric and Planetary Sciences and Physics and a scientist at MIT Kavli Institute for Astrophysics and Space Research, discusses her life and the way her studies and the people she met along the way helped to ground her and yet also help her find lofty goals and hope. As the book description states: “Probing and invigoratingly honest, The Smallest Lights in the Universe is its own kind of light in the dark.”

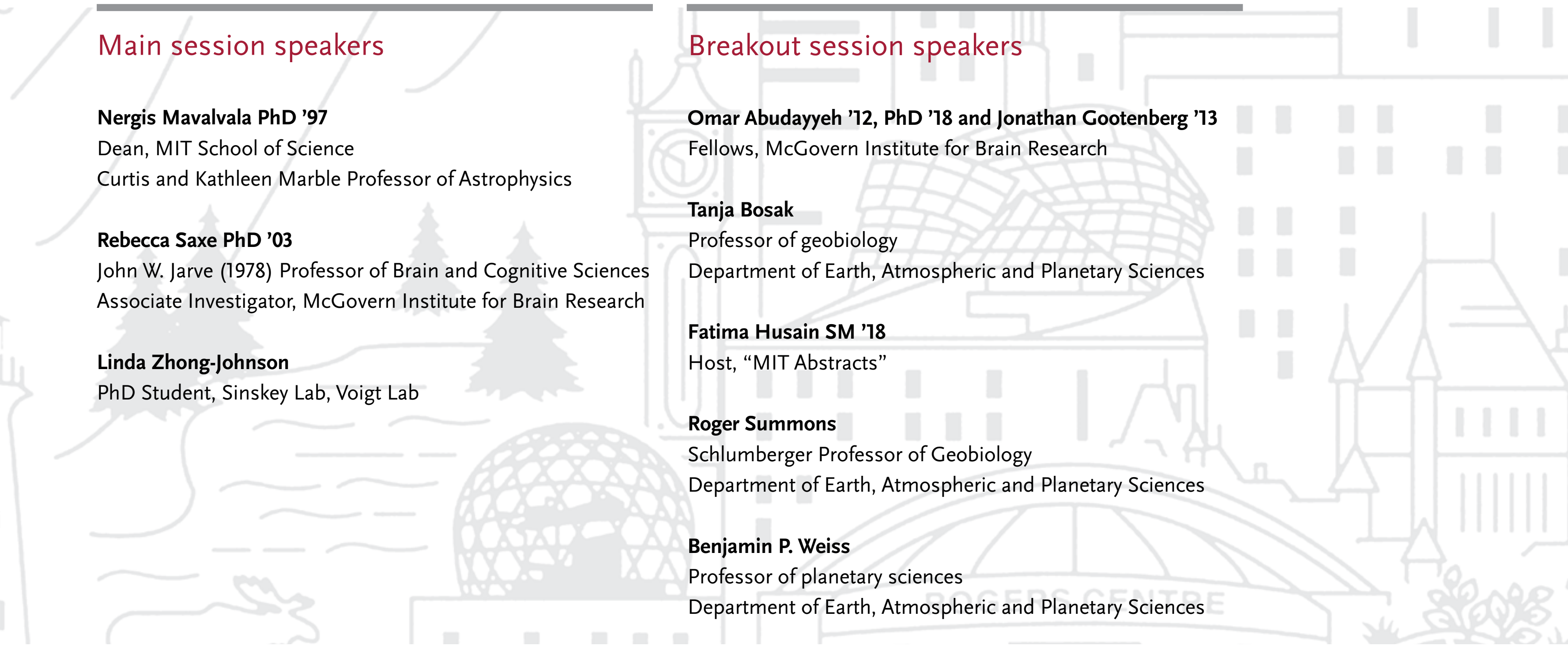
“I think everyone can take away something slightly different, but I hope that people can see at least my side of the story, my corner of space,” Seager told Space.com in an interview about the memoir. “I hope that people who didn’t know a lot about exoplanets can walk away knowing about this incredible, evolving field of astronomy.”

Find out more about the book at Crown Publishing. Read more of her interview, “*The Smallest Lights in the Universe* Explores the Possibilities of Life on Earth and Far beyond It” at Space.com.

MIT Better World: Science and Discovery

At a time when the world looks to the scientific community for solutions, we heard insights from Institute leaders, faculty, students, and alumni in global pursuit of scientific knowledge at a special virtual Better World event held on November 17, 2020.

Visit betterworld.mit.edu/events/science to watch recordings from the event.



Main session speakers

Nergis Mavalvala PhD ’97
Dean, MIT School of Science
Curtis and Kathleen Marble Professor of Astrophysics

Rebecca Saxe PhD ’03
John W. Jarve (1978) Professor of Brain and Cognitive Sciences
Associate Investigator, McGovern Institute for Brain Research

Linda Zhong-Johnson
PhD Student, Sinskey Lab, Voigt Lab

Breakout session speakers

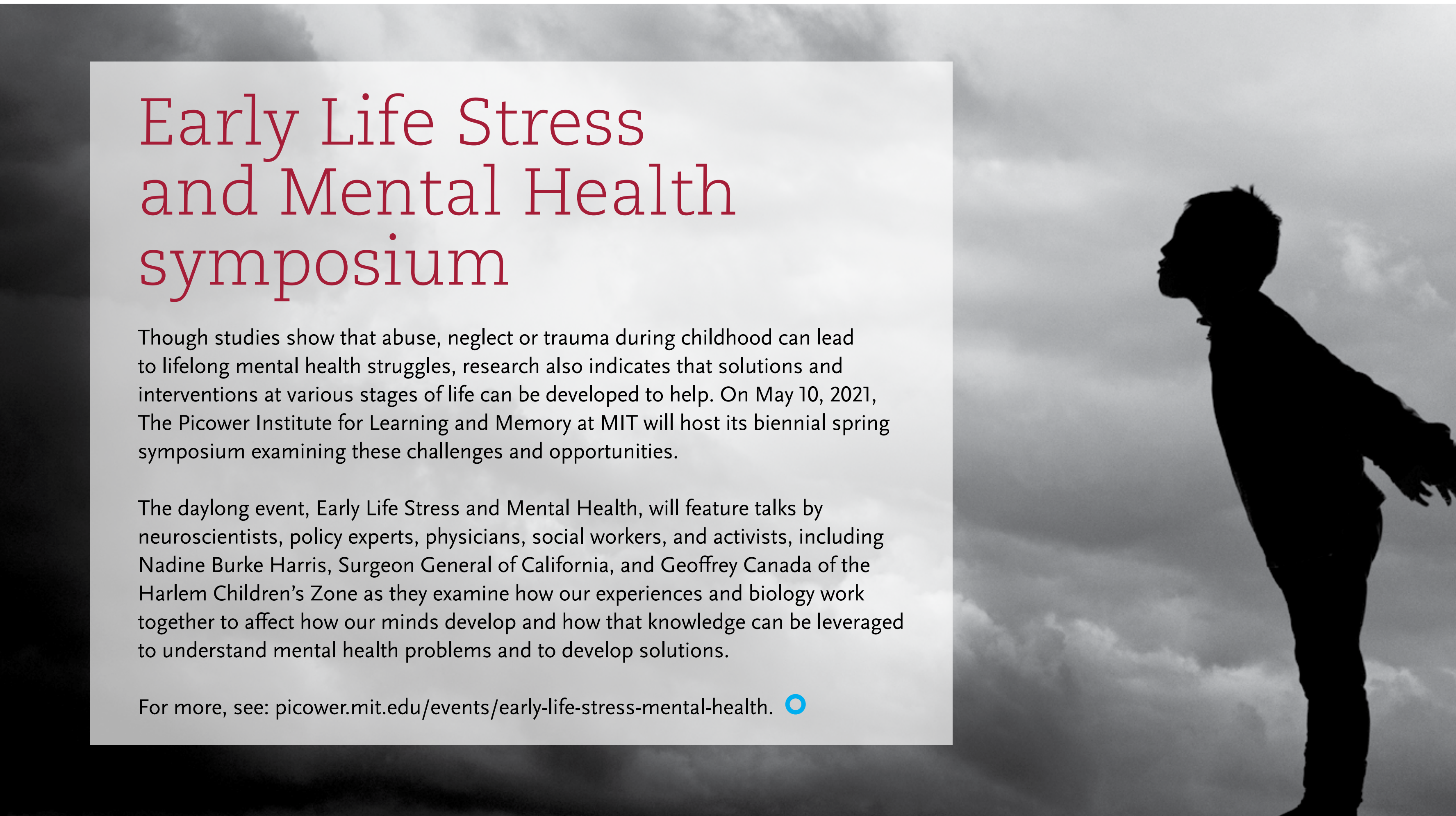
Omar Abudayyeh ’12, PhD ’18 and Jonathan Gootenberg ’13
Fellows, McGovern Institute for Brain Research

Tanja Bosak
Professor of geobiology
Department of Earth, Atmospheric and Planetary Sciences

Fatima Husain SM ’18
Host, “MIT Abstracts”

Roger Summons
Schlumberger Professor of Geobiology
Department of Earth, Atmospheric and Planetary Sciences

Benjamin P. Weiss
Professor of planetary sciences
Department of Earth, Atmospheric and Planetary Sciences



Early Life Stress and Mental Health symposium

Though studies show that abuse, neglect or trauma during childhood can lead to lifelong mental health struggles, research also indicates that solutions and interventions at various stages of life can be developed to help. On May 10, 2021, The Picower Institute for Learning and Memory at MIT will host its biennial spring symposium examining these challenges and opportunities.

The daylong event, Early Life Stress and Mental Health, will feature talks by neuroscientists, policy experts, physicians, social workers, and activists, including Nadine Burke Harris, Surgeon General of California, and Geoffrey Canada of the Harlem Children’s Zone as they examine how our experiences and biology work together to affect how our minds develop and how that knowledge can be leveraged to understand mental health problems and to develop solutions.

For more, see: picower.mit.edu/events/early-life-stress-mental-health.

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A new MIT study in *Nature Neuroscience* reveals that encoding memories in engram cells is controlled by large-scale remodeling of the proteins and DNA that make up cells' chromatin.

In this image of the brain, the hippocampus is the large yellow structure near the top.
🟢 Green indicates neurons that were activated in memory formation; 🔴 red shows the neurons that were activated in memory recall;
🔵 blue shows the DNA of the cells; and 🟡 yellow shows neurons that were activated in both memory formation and recall,
and are thus considered to be the engram neurons.
Image: courtesy of the Tsai Lab