Spectrum

Massachusetts Institute of Technology
Spring 2024

WHAT'S NEXT? WHAT'S NEXT?

PHOTO: KEN RICHARDSON

(↗)

THE STATE OF ELECTIONS

Charles Stewart III, the Kenan Sahin Distinguished Professor of Political Science and founding director of the MIT Election Data + Science Lab, takes stock of the election system.

READ MORE AT
betterworld.mit.edu/spectrum/elections

(↗)

ENVIRONMENTAL JUSTICE FOR ALL

Researching "forever chemicals," postdoc Moala Bannavti advocates for equity in remediation efforts.

READ MORE AT
betterworld.mit.edu/spectrum/bannavti

Wide Angle

Subjects

What's Next?

Community Highlights

Spring 2024

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617.253.0800
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"One of my favorite things about the MIT community is the incredible spirit of openness and intellectual generosity. I am a cell biologist, but when I'm curious about work in another discipline — anything from promising climate solutions to novel uses of generative AI to new quantum optics — all I have to do is start asking questions. Very quickly I'll find myself in conversation with some of the most brilliant, innovative people in the field."

SALLY KORNBLUTH

PHOTO: GRETCHEN ERTL

“The building is a physical embodiment of the MIT Stephen A. Schwarzman College of Computing, focused on the breadth and depth of computing and standing as a vibrant hub that enriches the entire campus community with a collective spirit of innovation, collaboration, and possibilities.”

DANIEL P. HUTTENLOCHER SM ’84, PHD ’88
Henry Ellis Warren Professor of Electrical Engineering and Computer Science
Dean, MIT Stephen A. Schwarzman College of Computing

250
Seats in second-floor lecture hall

174,000
Gross square feet

340
Capacity of event space on top floor

50
New and existing faculty members in the college

PHOTO: BOB O’CONNOR

90
Closed cavity glass panes on south façade — expected to significantly reduce energy consumption

4
Levels of space for computing research groups

A State-of-the-Art Space for Sparking Innovation in Computing and AI

Dedicated in April, the striking new home of MIT's Stephen A. Schwarzman College of Computing opens the college to the world.

The transparent and outward-looking design of the new Building 45 gives passersby a direct view into the first two floors and the central core. The shingled-glass façade creates a distinctive visual cue: along with insulating the building, the floor-to-ceiling glass encourages interaction and engagement between the community and the college.

Located on Vassar Street steps from Kendall Square, with open spaces for studying and socializing on the ground floor, the new college building is already becoming a destination for MIT students and visitors alike.

Meantime, the top floor, eight stories up, houses MIT's newest signature event space, with stunning views across Cambridge and Boston.

Designed by Skidmore, Owings & Merrill, a firm that has created some of the most technically and environmentally advanced buildings in the world, the MIT Schwarzman College of Computing building offers state-of-the-art space for computing education while serving as a nexus for interdisciplinary teaching and research.

In keeping with MIT's commitment to environmental sustainability, the building is tracking towards Leadership in Energy and Environmental Design Gold certification.

The glass shingles forming the building's south-facing side not only provide ample natural light, but also form a double-skin façade constructed from interlocking units that create a deep sealed cavity, which is expected to significantly reduce energy consumption. Other sustainability features include embodied carbon tracking, on-site stormwater management, and a green roof.

Situated next door to Building 46 — home to the Department of Brain and Cognitive Sciences, The Picower Institute for Learning and Memory, and the McGovern Institute for Brain Research — and connected at the third floor, the Schwarzman College of Computing building encourages collaboration across and beyond MIT through an open design that sets the stage for spur-of-the-moment interactions. On four levels are research spaces created for a computing faculty and their research groups across a broad range of areas.

For a college that describes itself as "reshaping the computer age," the new Building 45 serves as an energetic hub. –Mark Sullivan

(↗)
Read more about the Schwarzman College of Computing on page 26.

Our Fandoms, Ourselves

Students explore fan culture as "a powerful tool for social engineering"

TITLE

CMS.621 Fans and Fan Cultures

INSTRUCTOR

Edward Schiappa, John E. Burchard Professor of the Humanities (Fall 2023)

ILLUSTRATION: MAX-O-MATIC

FROM THE CATALOG

CMS.621 Fans and Fan Cultures, a communication-intensive elective in Comparative Media Studies/Writing, examines media audiences—specifically, fans—and the subcultures that evolve around them. Students examine the different historical, contemporary, and transnational understandings of fans and explore products of fan culture, i.e., clubs, fiction, "vids," activism, etc. Readings place these products within the context of various disciplines. Students consider the concept of the **"aca-fan"** and reflect on their own "fannish" practices.

The term "aca-fan" describes individuals who primarily identify as academics and also identify as fans. Henry Jenkins, the former MIT professor who created CMS.621, embraced the term and used it to describe himself.

CLASS STRUCTURE

"I truly believe the structure of our society is built on fandom," says Skipper Lynch '26, a physics major. In the fall 2023 session of CMS.621, Lynch's written and oral presentations explored fan phenomena as recognizable as *Scooby-Doo* and as niche as *The Magnus Archives* horror podcast. "I see fan culture as a powerful tool for social engineering, which goes hand in hand with the other forms of engineering at MIT."

Fans and Fan Cultures uses a lens of popular culture to investigate connection: to peers, family, society, and one's self. As a communication-intensive course, it hones students' writing and presenting skills while applying **critical communication theories**. Most class time revolves around student presentations and discussion of three major projects: an oral history based on an interview with a person over age 50, an autoethnography about one's own fan experiences, and a normative assessment of a phenomenon in current or recent fan culture.

Uses and Gratifications Theory: sees media users as active agents who choose media to satisfy given needs as well as social and psychological uses, such as knowledge, relaxation, social relationships—unlike many media theories that view users as passive.

Cultivation Analysis: asserts that high-frequency television and internet users are more susceptible to media messages and the belief that they are real and valid.

Social Learning Theory: proposes that learning that occurs through observation, imitation, and modeling is influenced by factors such as attention, motivation, attitudes, and emotions.

Edward Schiappa, the John E. Burchard Professor of the Humanities and former head of Comparative Media Studies/Writing, jumped at the chance to resurrect the course in 2021. He taught it in fall 2023, and other MIT instructors sometimes take up the mantle. The popular course was originally created and taught by former MIT professor **Henry Jenkins**, a pioneer of fan studies.

Jenkins's book *Textual Poachers: Television Fans and Participatory Culture*, 2nd ed. (New York: Routledge, 2013) was originally published in 1992 and is a foundational text for the course and for the field of fan studies.

"I've found that students really like to learn about media studies—even the drier empirical research on media effects—if they learn about it in the context of popular culture," Schiappa says. "Fan experiences are about more than just having fun. They are often important vehicles for learning about oneself, and for connecting with like-minded individuals." Students like Lynch also gain a deeper understanding about human behavior and how media ripples through cultural identity.

Fandom throughout the years

"Though fan cultures are discussed more and can spread more easily thanks to the internet, the importance and impact of fans is nothing new," says Schiappa. "Decades before Beatlemania, for example, stars like Frank Sinatra attracted huge mobs of fans. The biggest difference in the 21st century is a matter of scale. One can participate in fandom with the click of a button."

Students learn this firsthand in their first assignment—to interview a person over the age of 50 about their fandom experiences. **Sabrina Hu '25**, a computer science and media studies major, chose to interview her mother for the project. "I was nervous that I wouldn't have much content to work with, but I was very wrong," Hu says. "My mother nostalgically recounted her favorite childhood movies—I specifically wrote about *Xiao Hua* from 1979—and why she loved them so much, given the national and cultural context of growing up in China."

For Hu, the results of the interview assignment went beyond her presentation: "My mom grew up in China, and she and I have always had a language and cultural barrier. Talking to my mother about her fan experience helped me understand why she thinks the way she does, and we were able to grow closer through this assignment."

The personal nature of each project and changing tides of culture ensure that subjects are never the same in each semester, but one fandom will always remain on the syllabus: ***Star Trek: The Original Series***. "Much of what we study with respect to fan culture is a result of fan activities in response to *Star Trek*," Schiappa says.

Schiappa: "Fans of *Star Trek* did not originate the idea of a conference, but they took 'cons' to a new level. They also practically invented what we now call cosplay by coming to cons in costume."

Meaningful analysis

Students draw parallels not only to each other's fandoms, but how they affect their worldview at large. "One of the central themes of the class was that everything we watch has some sort of message it wants to convey to us, implicitly or explicitly—even children's television," says student Emily Ruben, who is cross-registered from Wellesley College. "My final project was on the political allegories in the show *The Legend of Korra* and how political messaging in pop culture can subtly influence our political beliefs. CMS.621 always had me thinking deeper about the media I consumed."

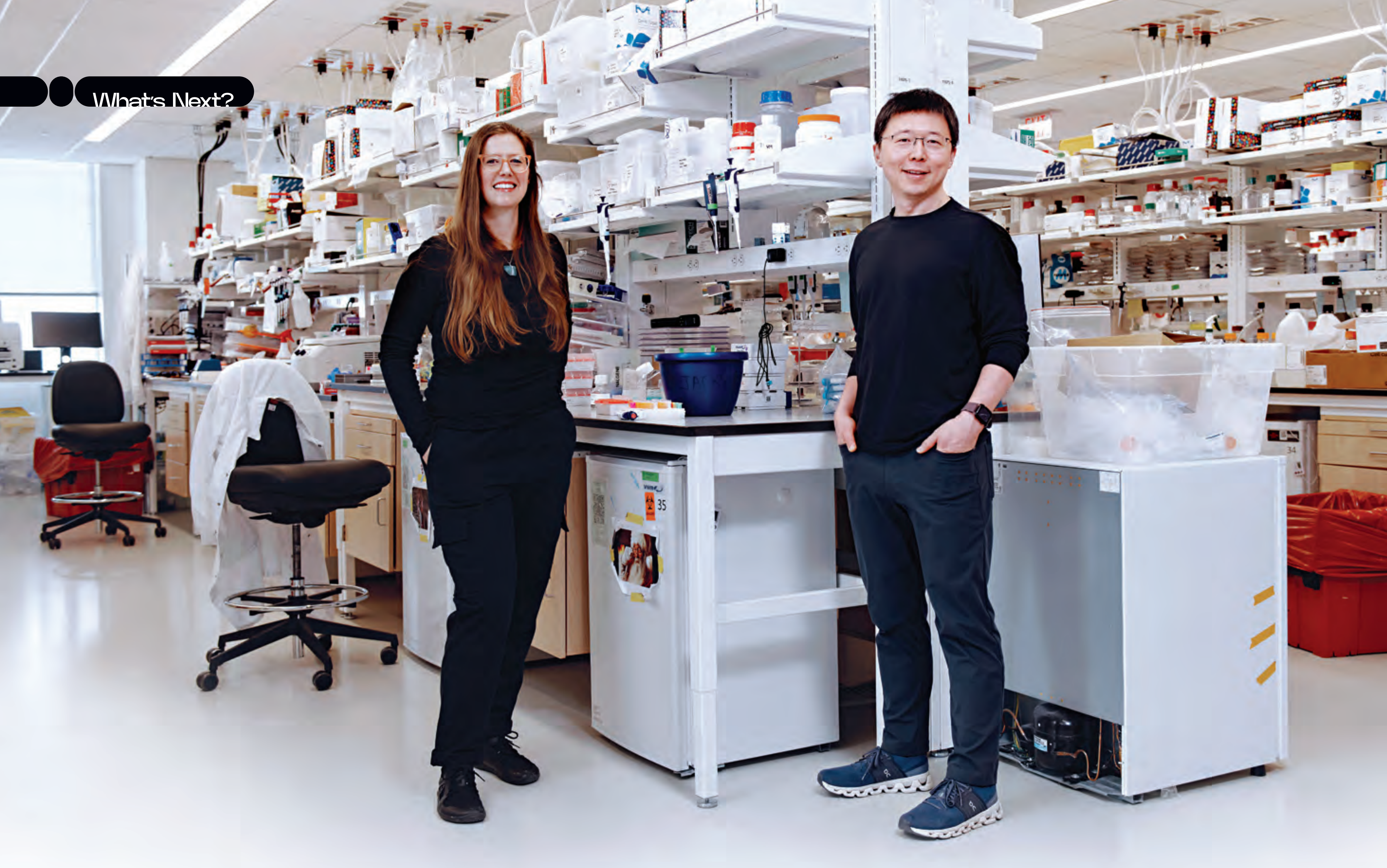
Self-examination and relating to others in a classroom context, however, is also an eye-opening experience for many students that flows into other areas of their lives and studies. "What we were learning in class was directly applicable to me and the people around me," Hu says. "It was so fun seeing everyone get excited about sharing a fan experience and relating to each other in that way." —Joelle Carson

What's Next?

When society is faced with seemingly intractable problems, MIT innovators don’t shy away from an uncertain future — they work to shape it for the better. Forming new collaborations across disciplines, our faculty and students seek out bold solutions and groundbreaking advances. What does the future hold for climate action? For CRISPR? For manufacturing? For AI? There’s no better place to ask, “What’s next?” in those fields — and many more — than at MIT.

A graphic exploration from designer and educator Vera van de Seyp, a research assistant in the Future Sketches group of the MIT Media Lab. Her work explores generative design tools, computational typography, and the use of artificial intelligence in graphic design. Through classes, workshops, and lectures, van de Seyp inspires makers to code and create their own design tools.

ILLUSTRATION: VERA VAN DE SEYP



From CRISPR Breakthroughs, Life-Altering Therapies

Fast-moving discovery in gene-editing arena leads to promising new treatments

For patients and families confronting painful and burdensome genetic disorders, scientists at the McGovern Institute for Brain Research have a message: your day has come.

"With recent, historic advances from MIT labs, it is clear we're now creating and rapidly expanding a genetic toolbox leading to new treatments," says Robert Desimone, McGovern director and the Doris and Don Berkey Professor of Neuroscience.

Among the milestones: In December 2023, the FDA approved Casgevy, the very first genome-editing therapy for sickle cell anemia based on the CRISPR-Cas9 technology developed by McGovern scientist and James and Patricia Poitras Professor of Neuroscience Feng Zhang. Gene replacement therapy from fellow McGovern scientist Guoping Feng, the James and Patricia Poitras Professor of Brain and Cognitive Sciences at MIT, will soon enter clinical trials for patients with a debilitating neurodevelopmental disorder. More gene-based remedies are on the way for diseases and disorders resistant to other treatments, fueled by basic discoveries from McGovern, the Broad Institute of MIT and Harvard, and allied research groups.

"These are really big home runs," says Desimone.

A DNA sequencing game changer

Eleven years ago, Feng Zhang shook up the biomedical world with news that he had adapted a genetic defense mechanism found in bacterial immune systems to snip out and repair DNA sequences in eukaryotic (animal and plant) cells.

"Researchers had been sequencing and identifying many different genetic mutations associated with very severe conditions, and there was this tantalizing idea that we could go into cells and fix them with CRISPR-Cas9, restoring mutations back to what their natural sequences should be," says Zhang.

Sickle cell disease results from a single-base pair mutation in the DNA of hemoglobin protein in red blood cells. The cells can't effectively move oxygen through blood vessels, often causing excruciating pain. Casgevy uses Zhang's gene-editing technology to repair the mutation in patients' blood stem cells and restore production of normal hemoglobin.

"This is the first time my research has moved into the world to relieve people's suffering, but I hope not the last," says Zhang. "It's incredibly rewarding and motivating as we try to advance CRISPR-based and other molecular technologies to treat many additional diseases."

Since 2013, Zhang and fellow researchers have refined gene-editing techniques to enable more precise targeting, editing, and replacement of DNA sequences, whether single bits of genetic code, or extremely long strands responsible for generating many proteins. Some of these innovations are now poised for clinical trials in such difficult-to-treat diseases such as muscular dystrophy, Alpha-1 antitrypsin deficiency (a condition that can spark chronic obstructive pulmonary disease and cirrhosis of the liver), and high cholesterol linked to cardiovascular diseases.

Barriers to progress remain

As significant as these advances are, formidable hurdles remain before gene therapy becomes an established, ubiquitous medical tool. "You can have this wonderful gene-editing system like CRISPR but the question is how you get it to the cells where it's needed," says Desimone. "Delivery is a giant problem."

Perhaps nowhere is this issue more apparent than in neurological diseases and disorders. "For people working on therapies for the brain, the big challenge is getting past the blood-brain barrier (BBB)," explains Feng. This membrane, evolved to protect the brain from infection and regulate the supply of vital chemicals and nutrients to the organ, proves a formidable shield. "Scientists have spent more than a century trying to figure out how to get even small molecules through," he says.

A scientist's journey

After two decades of meticulous research, Feng's work is paying off. He is pioneering a gene-based therapy that doesn't simply ameliorate but, if successfully demonstrated in humans, could actually reverse a kind of autism, identified in nearly 30,000 Americans, that is caused by a single mutation in the SHANK3 gene and causes severe cognitive, social, and motor skill deficiencies.

The breakthrough involves both a bold idea for replacing the flawed SHANK3 gene and an ingenious solution for delivering this remedy past the BBB and directly to neurons.

"Our first version for packaging this technology was far too large," he says. "We came up with a mini-SHANK3 suite that we believe will lead to a dramatic improvement in patients." With support from the Hock E. Tan and K. Lisa Yang Center for Autism Research, Feng genetically engineered the SHANK3 mutation in animal models using CRISPR-based technology. With marmosets, a small primate and ideal stand-in for humans, his gene-correction therapy greatly reduced SHANK3 symptoms, restoring the animals' cognitive, behavioral, and motor functions with no side effects, even after two years.

Far left: Postdoc Victoria Madigan and Professor Feng Zhang. Left: Professor Guoping Feng.

PHOTOS: TONY LUONG

Based on the safety and efficacy of these and other studies, the FDA approved JAG201, the SHANK3 minigene package licensed from Feng's lab by Jaguar Gene Therapy, for human trials starting in 2024. If the treatment works as planned, says Desimone, "It could mean that someone doesn't need to be institutionalized, or could live at home or in the community, which would be huge."

Next steps

While this treatment was many years in the making, Feng sees the next gene therapies arriving at a quickening pace.

"Genome editing took a long time to refine, but applying each development to a new disease treatment will be much shorter because we have the basic platforms now," says Feng. "Our experience using CRISPR and AI to model the genetics and cellular systems, design and test the delivery systems, will dramatically reduce time to treatment."

Complex neurological disorders

Major challenges lie ahead for researchers hoping to gain traction on many other neurodevelopmental disorders, as well as dementia and mental illnesses like schizophrenia and depression. Here, they must identify and fix multiple genes rather than a single mutation, determine the impacts on a panoply of proteins these genes express, and then find a method for deploying their therapeutic payload exactly where it is needed, without unwelcome side effects.

"We need to get to the next step, which is scaling up our therapies and achieving targeted delivery of editing enzymes," says Victoria Madigan, a postdoctoral fellow at the McGovern Institute. Madigan specializes in a class of protein structures called capsids—protective shells that can encase genetic material and transfer it from cell to cell.

"It's always a good idea to learn from Mother Nature," she says. "I'm studying a family of capsids that are naturally found in the human genome and are produced in great volumes by neurons in the central nervous system, trying to learn how we can make them effective gene delivery modalities," she says.

Madigan and fellow researchers are bent on modifying capsids to carry ever-more-complex gene-editing cargo that will produce only those proteins that impact the target disorder. Their vision is to rewire genetic machinery that could restore function or even head off the degenerative effects in patients with such diseases as Huntington's and Parkinson's.

Other McGovern and MIT labs are exploring different mechanisms for accurate delivery of therapies for multigene diseases. One approach involves coating the gene-altering packages in lipid nanoparticles, along the lines of those used to make the Covid-19 mRNA vaccines. Researchers at the Zhang lab developed a microbial syringe system and co-opted it to deliver gene-editing enzymes. "It functions on the molecular level just like a real syringe, with a spring-loaded mechanism that shoves the proteins right into the cell," says Zhang. Biotech firms have already expressed an interest in this early-stage microdevice for treating disorders in the kidney and brain.

"As molecular biologists, we focus on the basic technology platform, trying to make that as robust and widely applicable as possible, so many groups can apply it to whatever disease they have expertise in," says Zhang.

Researchers in the field express genuine optimism about what comes next. "I think we're just going to see so much happen in the next 10 years," says Madigan. "CRISPR-Cas9 has taken off and become useful for so many different things. I'm very hopeful that we can have substantial impacts on human health." —Leda Zimmerman

Changing Real Estate's Carbon Footprint with Data as a Guide

MIT researchers work to propel the industry toward sustainability

Real estate is a massive industry, with buildings generating an astonishing 39% of carbon emissions worldwide. Production of cement, concrete, and steel for construction contribute one third of those emissions, while operational carbon released during heating, cooling, and electricity accounts for the rest.

In many US cities, lawmakers have announced ambitious targets to achieve net zero (a balance between the greenhouse gas that's produced and the amount that's removed from the atmosphere) in the next few decades. This puts real estate leaders under pressure to help meet these targets while still making a profit. An abundance of technological innovations and incentive programs are available, but adoption by the real estate industry remains low due to barriers such as a lack of reliable information and confusion about upfront costs.

"My work focuses on how to accelerate the adoption of all the new decarbonization technologies and how to improve the resilience towards climate risks in the real estate industry, how to identify the barriers and create new policy or market mechanisms to speed up this sustainable transformation," says Siqi Zheng, the STL Champion Professor of Urban and Real Estate Sustainability in the Department of Urban Studies and Planning and faculty director of the MIT Center for Real Estate and the MIT Sustainable Urbanization Lab.

Zheng's work in this area with the Center for Real Estate is supported by an MIT Fast Forward Faculty grant created by the MIT Climate Nucleus to catalyze interdisciplinary teams of climate and sustainability leaders from across the Institute.

"The real estate industry is so huge and so traditional," says Zheng. "From development to asset management, and to investment, practitioners hadn't really put the climate issue onto their 'most important' agenda."

Faced with clear signs of climate change such as rising sea levels as well as the pressure of government initiatives, however, industry leaders are showing more enthusiasm for data-informed solutions to reduce their properties' carbon footprints and increase their resilience in the face of both physical and transition climate risks.

Zheng's projects under the Fast Forward Faculty Grant umbrella create pathways for institutional investors and pension fund managers to decarbonize the assets in their portfolios through investment matching and through physical upgrades in properties.

In one collaboration with Roberto Rigobon PhD '97, the Society of Sloan Fellows Professor of Management and professor of applied economics at the MIT Sloan School of Management, Zheng and her team use an iPad-based, algorithm-powered questionnaire to help real estate investors better understand their assets through the environmental, social, and governance (ESG) framework. "We're trying to help them connect Wall Street with Main Street to maximize the social value of all their investments," says Zheng. "That way they can effectively align their financial performance goal with environmental and social goals, instead of just randomly talking about ESG."

Collaborating with Christopher P. Knittel, the George P. Shultz Professor of Energy Economics and professor of applied economics at MIT Sloan, Zheng's team also studies how best to increase adoption of heat pumps, the most efficient building electrification technology. By reducing homes' reliance on oil and gas for heating and cooling, high-efficiency electric heat pumps are another energy game changer, reducing homes' reliance on oil and gas. But to meet many of the net-zero targets proposed across the United States and Europe, installation of these systems would need to triple, from the 180 million installed by 2020 to 600 million by 2030. "What's the pathway?" asks Zheng. "The adoption is so low, even with all the subsidies from the Inflation Reduction Act. So we are doing research to identify the key barriers. Then we will talk to community-engagement programs and see how we can really work together to promote this."

Zheng and her team hope to expand their efforts beyond the United States to work with fast-growing economies around the world. "Industry leaders need new knowledge, some science-based decision-making support," says Zheng. "The timing is good for MIT's Center for Real Estate to become the intellectual leader on this new ground."

—Stephanie M. McPherson

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PHOTO: BRYCE VICKMARK

K–12 Education in the Era of Generative AI

MIT researchers explore how technologies like ChatGPT can be best harnessed to enhance learning and creativity

After its release in November 2022, ChatGPT became the fastest-growing application in history, attracting 100 million users within a few months. People were understandably intrigued by this powerful new tool—the highest-profile exemplar of so-called generative AI—which can, within a few seconds and after a few prompts, create text, images, music, and computer programs.

Even before ChatGPT became part of the popular discourse, MIT was looking to the future of AI. Building on that experience, the Institute provided exploratory funding in the fall of 2023 for more than two dozen research proposals aimed at determining how this new technology might be utilized for societal good and identifying potential pitfalls to be avoided. Four MIT researchers—Hal Abelson PhD '73, the Class of 1922 Professor of computer science and engineering; Cynthia Breazeal SM '93, ScD '00, MIT dean for digital learning and professor of media arts and sciences; Eric Klopfer, professor and director of the Scheller Teacher Education Program and The Education Arcade at MIT; and Justin Reich, associate professor of digital media in MIT Comparative Media Studies/Writing and director of the Teaching Systems Lab—received a grant to explore the implications of generative AI on K–12 education.

Fear of the unknown

"A lot of the initial perspectives focused on worries about students using generative AI to cheat on papers," says Klopfer, who leads the MIT Comparative Media Studies/Writing program. Although that concern must be addressed, he maintains, "we are trying to change that conversation. Schools are not walled gardens separate from the rest of the world. Since the rest of the world has access to these tools, students need to know how to use these tools effectively."

"Banning technology doesn't work well," adds Reich. "It just encourages students to figure out ways of getting around those bans." Nevertheless, there are ways of walling off technology, at least temporarily. Teachers, for instance, can prevent students from using calculators in class until they establish proficiency in arithmetic. Once they've done so, students can use calculators to free up time for more intellectually challenging math problems.

Writing assignments can teach students to not only write but also to think. "So we need to be careful about introducing technology that enables students to bypass the kind of thinking we want them to do," Reich says. The challenge for teachers, he observes, is to figure out what things we should let ChatGPT do and what things we should prevent it from doing.

New technology, familiar challenges

This dilemma is by no means novel. Schools had to devise policies governing the use of calculators, indicating when their use is permissible and even desirable. With the internet widely accessible in US schools for the last 25 years, educators like Reich, who taught high school history from 2003 to 2007, worried about whether students were cutting and pasting material from online into their papers. Yet this technology also brought obvious advantages: students could quickly gather information from books, newspapers, and journals, providing more time for reading and processing information, rather than rummaging through library stacks or poring over microfilm.

The hope is that generative AI can—if properly applied—offer benefits to K–12 education that greatly outweigh its potential downside. In the road map the MIT researchers have prepared for schools, they have spelled out what a "brighter future" for AI in education could look like, detailing the key steps needed to achieve that vision.

"Kids learn by creating things," says Klopfer, and generative AI can help them do that in myriad ways. He points to Aptly, a software platform recently developed by Abelson along with an MIT software engineer and two undergraduates, "as representative of the kind of things we want to point children toward." Aptly makes the chore of designing apps for a smartphone easy. "You can speak to your browser and say: 'Make me a smartphone app with a few buttons, each corresponding to a different language,'" Abelson explains. "When I press a button, translate what I speak to that language."

The range of apps you can make is essentially unlimited, Abelson says. "If a computer can make any kind of program you want, we then have to decide what to teach our kids in terms of computing. And once you make what you wanted, how would that benefit the world?"
—Steve Nadis

ILLUSTRATION: NHUNG LE

A Plan for Plants

Voigt Lab uses synthetic biology to build a future of climate-resilient crops grown with lower emissions

As a fledgling assistant professor at the University of California San Francisco, Christopher Voigt faced a pivotal moment that almost led to him abandoning academia. When the principal investigator on a multimillion-dollar grant abruptly pulled out of a project, Voigt had eagerly stepped up, writing an entire section from scratch on how to use synthetic biology to improve photosynthesis. "I was like, this is my big opportunity," he recalls. Yet, when the grant reviews came back, Voigt's section tanked. It was a devastating blow. He even told his wife he was quitting.

But then a colleague invited him to a meeting and said, "You just picked the wrong system. If you take these same ideas and apply them to nitrogen fixation, you could have a real impact."

Those words changed the course of Voigt's career. He and his then-nascent lab plowed into the challenge of using synthetic biology—advanced genetic engineering—to supply agricultural plants with the nitrogen they need to grow and flourish.

The team published a groundbreaking paper demonstrating the technique in 2012, around the time Voigt was recruited to MIT, where he is now the Daniel I.C. Wang Professor and head of the Department of Biological Engineering. In those early days, MIT, notably the Abdul Latif Jameel Water and Food Systems Lab, provided Voigt with critical startup funds to sustain and amplify his research.

Nitrogen fixation

Here's the problem Voigt is trying to solve: There is plenty of nitrogen gas in the atmosphere, but in that form, it's inaccessible to most plants.

Some species partner with bacteria that use special enzymes to convert—or "fix"—nitrogen gas into ammonia, which the plants then use. But Voigt says that corn, rice, and wheat—which constitute about half the calories we consume—can't do that. Without sufficient nitrogen, a plant like corn yellows, wilts, and becomes stunted, producing fewer and smaller ears. The result, in other words, is easily visible; it's not "something that's hidden or under the earth," says Voigt.

To provide crops with the nitrogen they need, farms tend to smother them with artificial fertilizers, dumping millions of tons of ammonia onto the soil every year. Making these fertilizers requires enormous amounts of energy and creates about 2.5% of global greenhouse gas emissions.

Fertilizers are also heavy pollutants. Voigt says that half of what gets poured or sprayed onto the soil ends up in the water and air. In fact, soil bacteria convert a good amount of fertilizer's artificial ammonia into nitric oxide, which is "almost 300 times worse than carbon dioxide as a greenhouse gas," he says.

Voigt's challenge, therefore, is to develop a different way to feed nitrogen to crops. Ultimately, his answer was to reconstruct the genes of nitrogen-fixing soil bacteria "from the ground up" to get the

On working to create "self-fertilizing" plants and generating less pollution, Voigt says, "I feel like we're getting close."

microbes to coat the roots of the plant as it grows. Then, as the bacteria convert nitrogen gas in the soil into ammonia, the plant can take it up directly. This is the work that he and his team are championing at MIT.

Since joining the Institute, Voigt has found ways to create variations on nitrogen fixation, allowing him to transfer the pathway to different bacterial species that are easier to manipulate. Currently, a set of his modified microbes are mixed in with corn seeds just before they're planted in the soil. They supply the plants with 20% to 40% of their nitrogen, dramatically reducing the amount of fertilizer needed.

He has also altered *Azorhizobium caulinodans*—a bacterial species that does a particularly good job at grabbing onto nitrogen in the air—to ramp up nitrogen fixation in the presence of certain chemicals. After one of his collaborators engineered barley to produce and release those chemicals, Voigt helped demonstrate how the altered plant attracted *A. caulinodans* to colonize its roots where it then accelerated the fixing of nitrogen.

Scaling up farming sustainability

In 2011, Voigt and two of his students spun out a company, Pivot Bio, to license and scale up the technology and bring it to commercial farms across the United States. "It's now a multibillion-dollar company," says Voigt. Their product is used on about five million acres of farmland in this country, amounting to about 6% of the US corn crop.

Voigt is leading one of the projects in MIT's Climate Grand Challenges (CGC), an Institute-wide effort launched in 2020 to mobilize the research community around unsolved climate problems. After more than 100 letters of interest from faculty, five projects were chosen for support, all of them offering interdisciplinary solutions and plans for rapid and large-scale implementation. Voigt's team seeks to revolutionize agriculture by improving nitrogen distribution within plants, enhancing seed coatings to keep bacteria alive for longer, and fortifying crops to withstand climate change.

To Voigt, the CGC funding provides an opportunity to tackle the next phase of the nitrogen fixation problem. He plans to work with "more complex microbes that can fix nitrogen over a wider range of conditions, create genetic sensors that control the process so that it occurs only when it's close to the root and not in the soil, and ramp up the overall amounts of nitrogen supplied through this technique."

Voigt traveled to Kenya with students in the summer of 2023 to see nitrogen fixation technology in action. One of the first things he noticed was that fences are used to keep out hippos. He also noted a "dramatic difference" between the crops with the enhanced microbes (healthier, stronger stems) and those without. "The root systems are completely different when you pull them up," he says.

The future of food production

Voigt expects that within the next three years, modified bacteria will be able to supply plants with 60% to 70% of the nitrogen they need, with the ultimate goal of dropping the microbes altogether. He ultimately wants to genetically engineer corn and other plants to free them from their bacterial leash, allowing them to fix nitrogen on their own. This would require moving the microbial genes into the cereal crops.

Voigt and his team have been trying to create such "self-fertilizing" plants for eight years, inspired by a vision of feeding millions of people on the planet while generating less pollution. "I feel like we're getting close," he says. –Ari Daniel

Qiguo Yu, left, a postdoctoral associate in the lab of Christopher Voigt, right.

PHOTO: SIMON SIMARD

MIT's Responsibility to Lead in a Challenging World

JULIE A. LUCAS, the Institute's vice president for resource development, talks about the forward-looking MIT community and the Institute's vital role in addressing critical issues.

Since we're considering "what's next?" in this issue, how is MIT addressing the rapid adoption of AI in so many facets of life?

At MIT's Generative AI: Shaping the Future symposium in November 2023, President Sally Kornbluth eloquently made the case that the Institute has an obligation to help society understand the potential of AI but also spread awareness of its potential challenges. Our alumni and friends are a key part of this work as they support the MIT community in its quest for innovation during a period of exceptional technological change.

In this fast-moving landscape, the Institute has launched a number of interdisciplinary projects and activities spanning generative AI policymaking, impact, entrepreneurship, technical advances, and education. One example of many is the use of deep learning and generative AI at the MIT Institute for Medical Engineering and Science, where these powerful new tools are already providing valuable information in the field of cardiovascular medicine (see story on page 20).

How is MIT responding to climate change, the defining challenge of our era?

Climate action is a top priority of the Institute, and MIT is uniquely positioned to help forge solutions. Our cross-disciplinary initiatives and research activities around energy, the environment, and access to water and food have global reach, with MIT alumni and friends providing critical support.

A new, whole-of-MIT mobilization, the Climate Project at MIT, will bring our community together to identify critical gaps in the global climate response and experiment with novel ways to deploy our intellectual resources and engage external partners to tackle them. The initiative will be shepherded by new, dedicated Institute climate leadership.

Our exceptional students bring boundless energy to this problem, and at MIT they learn from experts on topics such as clean-energy technologies and how to make crops more resilient. Philanthropy makes it possible for us to hire climate-focused faculty and to establish new fellowships that attract the best graduate students. If we can give our investigators the tools to pursue new ideas, some of the discoveries made at MIT will surely change the world.

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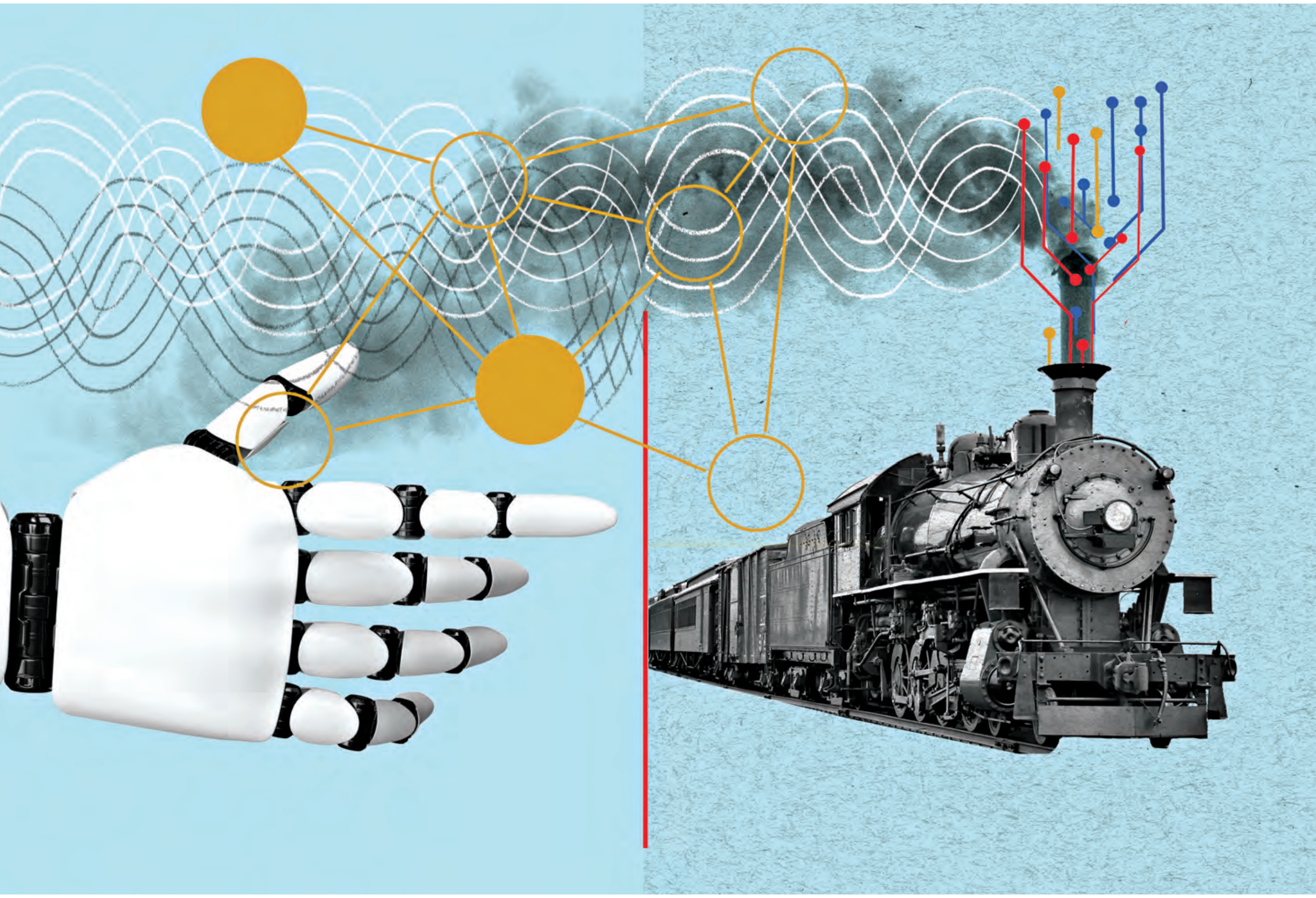
FOR MORE ON THE CLIMATE PROJECT AT MIT, VISIT
betterworld.mit.edu/the-climate-project



Worker, Meet Machine

The choices we make now will determine AI's influence on work in the future

If history teaches us anything about new technologies, it's that the promise of increased productivity and leisure is not all it's cracked up to be when it comes to those who actually do the work. "There is always a struggle over how technology is going to be used and who benefits from it," says Institute Professor in the Department of Economics Daron Acemoglu. "And when technology goes down the path of automation, it's not very beneficial for workers." Heeding that lesson is crucial when considering the role AI will play in society. When it is used to automate tasks that can be performed by humans—as has often been the case up until this point—it will lead to worker replacement and lost jobs. But history has another lesson as well, he says: "An alternative path is often open, where you can use technology in a more pro-worker way."

Acemoglu has spent much of his career looking at lessons of history. With University of Chicago Harris School of Public Policy political scientist James A. Robinson, he wrote the acclaimed *Why Nations Fail: The Origins of Power, Prosperity and Poverty* and its follow-up, *The Narrow Corridor: States, Societies, and the Fate of Liberty*, about how states can balance political liberty and economic

ILLUSTRATION: ANDREA D'AQUINO

Thus far, “the benefits of automation have been hugely exaggerated, and the productivity benefits are not as major as people have expected,” says Acemoglu.

success. More recently, he and Simon Johnson PhD ’89, the Ronald A. Kurtz Professor of Entrepreneurship at the MIT Sloan School of Management, wrote *Power and Progress: Our Thousand-Year Struggle Over Technology and Prosperity*. Acemoglu, Johnson, and Ford Professor of Economics David Autor are faculty co-directors of the new MIT Shaping the Future of Work initiative, which will identify innovative ways to improve job quality and labor market opportunities for non-college workers. “We have a lot to learn from the last 1,000 years,” Acemoglu says.

Scientific advances distributed unequally

While technology has led to material success, it’s also led to rampant inequality. From industrial robots to computers, recent technologies have been often used to replace human workers, concentrating wealth in the hands of owners. Yet that has not always been the case. Railways, for example, fundamentally disrupted the means of production and transport in a way that ultimately led to the creation of more jobs, including train engineers, conductors, firemen, ticket sellers, and maintenance workers.

Some digital technologies have also created jobs, when governments and firms have invested in helping workers attain new skills, as in Germany and Japan, by training workers to do more maintenance and inspection tasks as robots were introduced.

We stand at the same crossroads with AI, says Acemoglu, who has researched the topic for more than a decade—long before the recent explosion of generative AI. Thus far, he says, “the benefits of automation have been hugely exaggerated, and the productivity benefits are not as major as people have expected.” In a 2022 paper for the *Journal of Labor Economics* titled “Artificial Intelligence and Jobs,” for example, he and several colleagues found companies that started posting more AI-related vacancies between 2010 and 2018 stopped asking for some skills and began demanding new capabilities, but reduced overall hiring, a sign that AI replaced human workers and offered relatively little productivity benefit.

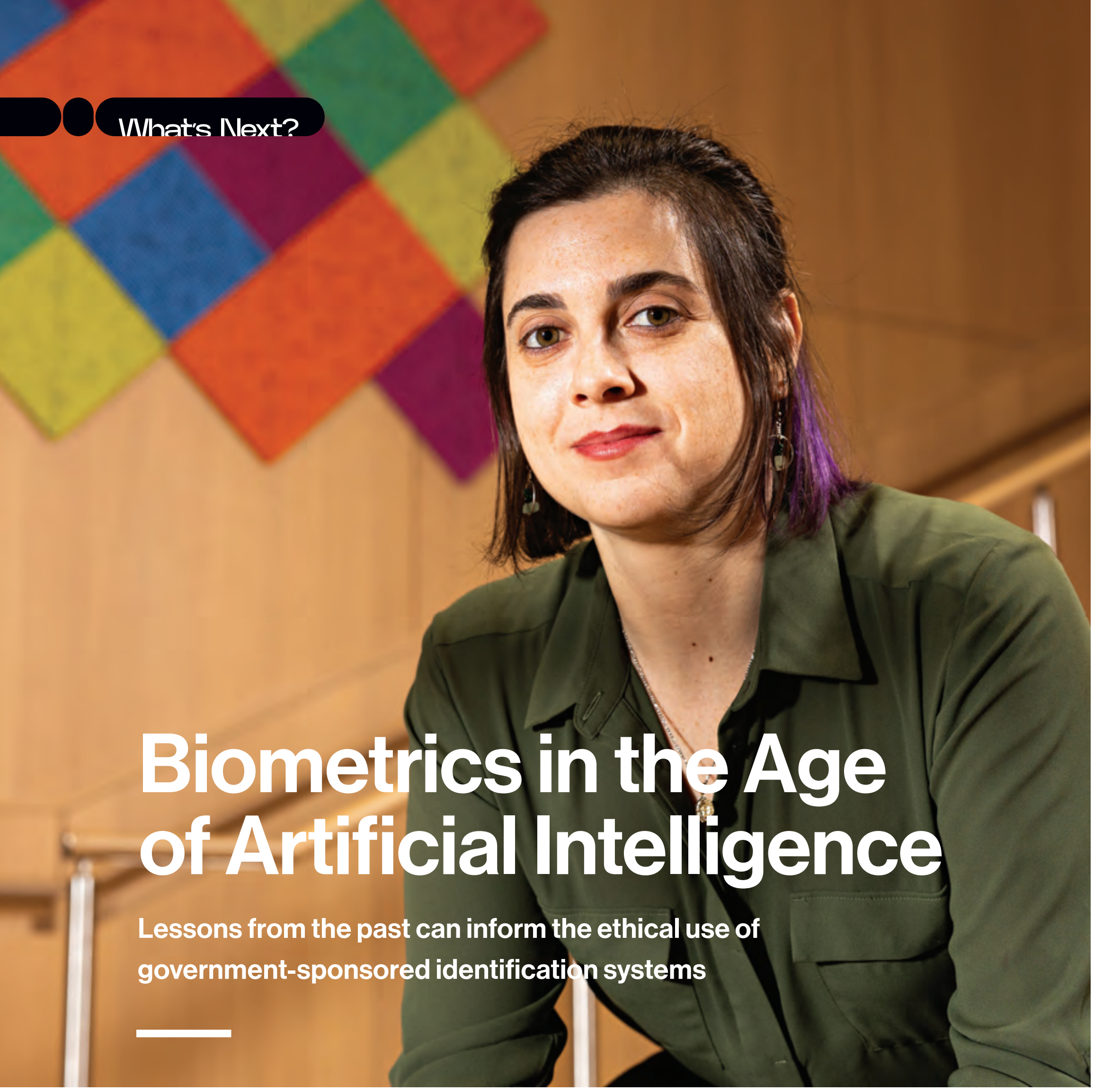
“We found that the establishments hiring people with specialized AI skills were precisely those that have tasks that can be automated by AI, and that once they do that, they start cutting their hiring,” Acemoglu says. It doesn’t have to be that way, however, given the incredible versatility of AI. Almost by definition, AI has capabilities that are very distinct from human skills, he argues, doing things well that humans don’t—but also not being as good at some things humans do well. “That creates the possibility for human-machine symbiosis.”

For example, AI is very good at analyzing large amounts of data and diagnosing problems. In fields such as education and health care, that can lead to the development of personalized strategies for teaching or treating patients by augmenting rather than replacing the skills of teachers and doctors. “By identifying what challenges a specific student is facing, it’s a pathway to personalized education, which would otherwise be prohibitively expensive,” Acemoglu points out. The same can be said for manufacturing or specialized workers, such as electricians, currently in short supply. AI could be used as a training and diagnostic tool for troubleshooting problems, improving worker productivity without replacing workers.

A fresh look at AI

Really shifting from automating to augmenting human tasks will take a sea change in the way we consider AI, Acemoglu says. Government would need to create incentives to this kind of AI research through the National Institutes of Health and the National Science Foundation, subsidizing AI in the same way it helped get the renewable energy industry off the ground. Changes could be made in the tax code, which currently levies higher taxes on firms that hire human workers than those that implement digital replacements. Policies could change around data ownership, compensating knowledge producers for the data they generate that AI models are now appropriating for free.

Just as importantly, says Acemoglu, the norms of the AI industry need to change, from its current attitude of “move fast and break things” to a more contemplative and nuanced approach that examines the consequences of its actions on the workplace and society overall. “We are unleashing technologies that are going to affect millions of people, and it’s important to have a recognition that these tools will have major seen and unforeseen consequences,” he says. The good news is that it is not too late to shift course; the choices we make in the near future will determine whether AI shapes work and society for the worse or for the better. “There is time, but not oodles of time,” Acemoglu says. “We are starting from the position that the industry is very powerful and regulatory muscle is lacking. On the other hand, there has been a true transformation in the conversation on AI over the last few years, and a much greater agreement that workers need to be at the table.” —Michael Blanding



Biometrics in the Age of Artificial Intelligence

Lessons from the past can inform the ethical use of government-sponsored identification systems

Biometrics, the measurement and analysis of human characteristics, have been used to identify and classify populations for more than a century. The fingerprinting of criminal suspects, for example, has long been standard practice for police. An explosion of technology over the past decade has broadened the reach of biometrics, which now help with such mundane tasks as unlocking our phones and allowing us to breeze through expedited security at the airport.

The capacity of biometrics has expanded thanks to the advent of AI- and algorithm-driven systems, adding a new ethical layer to the contentious issue of government surveillance.

Michelle Spektor PhD '23, the MIT-IBM Postdoctoral Fellow in Computing and Society in the MIT Stephen A. Schwarzman College of Computing's Social and Ethical Responsibilities of Computing (SERC), studies lessons from the past that can and should inform the use of biometric technologies in today's world. "I'm looking at the relationships between biometric identification and state power, politics of national belonging, inclusion, and exclusion in society, and thinking about how those dynamics change or stay the same over time, even as biometric technologies have been changing really significantly," she says.

A painful history

Biometrics are useful because of biological data unique to each individual; many physical characteristics are secure identifiers. Before becoming an aid in police work, colonial powers used biometrics to identify and control the people of their territories with often racist classification systems. Troublingly, biometrics were also developed by eugenicists, who aimed to "improve" the human race, in their view, by favoring certain groups over others.

In more recent decades, biometric data have been digitized and used by governments to help with situations such as disaster relief. "For a state to function, it does need to know who its citizens are," says Spektor. "Since their beginnings, nation states have used all different kinds of methods to know whom to deliver services to."

Many countries—examples include Nigeria, Estonia, and India—have national biometric identification systems to help verify eligibility for services such as welfare and health care. Spektor studies the connected history of British and Israeli biometrics from 1904 up to the proposal of national systems in both countries in the early 2000s. The UK program was eventually canceled, due in part to historical associations with criminality and oppressive governments. Israel's program remains in place despite opposition, and Spektor attributes its implementation to the longtime centrality of security, technology, and national identity in Israeli politics.

Not an infallible system

Biometric identification is by no means perfect. Spektor notes that, in the United States, biometric programs are constructed from datasets based on studies that focused traditionally on biomarkers of middle-aged white men.

"We know these systems don't work as well for people who aren't white men, for older people, and for people with disabilities," continues Spektor. "The stakes of misidentification could be, depending on the context, really high, and inequalities that already exist could be exacerbated."

Including AI in biometric identification can entrench these problems even further. One way past this, she observes, is to ensure humans are part of the process. Spektor urges governments considering new systems to consult with the communities that will be most impacted, and to explore whether or not a technological solution is even necessary. "Oftentimes the newest, most exciting technology is not going to be the thing that fixes problems—especially ones that are more structural and societal in nature," she says. She is working on a book that will share her perspectives with a wider audience, and is a contributor to a think tank that consults with US government agencies on technology policy.

An ethical way forward

Within the SERC Scholars Program, Spektor leads a project on surveillance, working with students "to develop a toolkit they can use in their studies and future careers, whether they're in engineering or tech policy or something else, so that they can promote the creation of more just and equitable technological systems that serve the public interest."

"Our goal," she continues, "is to foster an institutional culture in which we give just as much importance to accounting for the human impacts of the technologies we create, as we do to mastering the technical nuts and bolts of how to build these technologies."

—Stephanie McPherson

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PHOTO: JAKE BELCHER

A Fairer Path to Decarbonization

Roosevelt Project researchers build case for cleaner energy that brings greater economic opportunity to low-income communities

It's a harsh reality that many US workers lose their jobs when fossil fuel-based industries are phased out. The Roosevelt Project at MIT envisions a decarbonized world that doesn't leave anyone behind.

Initiated and led by former US Secretary of Energy Ernest J. Moniz, the Cecil and Ida Green Professor of Physics and Engineering Systems emeritus, the initiative engages local and national decision-makers in conversations on what a socially just post-carbon economy might look like. This is "not only the right thing to do, but essential to minimize political headwinds to make progress on the climate process," Moniz says.

"Our mission is to understand how the country could decarbonize while boosting economic opportunities for at-risk communities. If laws and bills are written correctly, these communities can grow while still decarbonizing," says Christopher R. Knittel, the George P. Shultz Professor of Energy Economics and professor of applied economics at the MIT Sloan School of Management and a Roosevelt Project researcher.

Named for three iconic Roosevelts—Teddy, for his stewardship of the natural world; Franklin, for the infrastructure-focused New Deal; and Eleanor, for her passion for social justice—the project, a three-phase initiative of the MIT Center for Energy and Environmental Policy Research, encompasses more than 30 MIT and Harvard economists, engineers, sociologists, urban planners, political scientists, and graduate students. The MIT research is supported by the Emerson Collective, which has longstanding interest in both social equity and climate.

Knittel's team looks at household carbon footprints, which depend on location, house size, energy usage, transportation habits, and waste production and can be the equivalent of 48 metric tons of carbon dioxide per year.

The average carbon footprint, Knittel found, is significantly higher in middle America than on the coasts. The disparity surprised him and underscored "the fact that decarbonization, if we don't do it right, can be very bad for the middle of the United States.

"We face real challenges, and addressing those challenges will require all of the relevant voices to be heard," he says.

The Roosevelt Project's first phase explored the effects of transitioning the economy toward deep decarbonization across socioeconomic groups, geographies, and economic sectors. With the input of local stakeholders, Phase 2 produced case studies of the effects of declining oil and natural gas production in Appalachia and the Gulf Coast, the effects of vehicle electrification on the Midwest's automotive and industrial centers, and the economic welfare challenges faced by underrepresented minorities in New Mexico.

Phase 3 provides a roadmap for policymakers to decarbonize industries in a "just, equitable, and clean way," Knittel says. For example, how to mine critical minerals such as lithium and cobalt without destroying habitats, how to funnel renewable energy transmission lines into populated areas without overrunning neighborhoods experiencing economic hardship, and how best to retrofit coal-burning steel plants with hydrogen.

The pie-in-the-sky goal of Phase 3, he says, "is to convince policymakers to support these industries in a way that is cognizant of the potential local environmental impacts. We need to understand—not just across socioeconomic groups, race, and ethnicity, but also geographically—how we could grow those communities as opposed to shrinking the opportunities those communities have," Knittel says.

The good news is that research points to the fact that this is doable. "Our modeling shows that you can decarbonize those regions in a way that can potentially grow the local economy in an environmentally sustainable way," he continues.

Since the project's inception, Moniz has held discussions with lawmakers, Congressional staffers, and members of the Biden-Harris administration. He's found stakeholders receptive to seeing the MIT and Harvard research on approaches that have worked—or not worked—in Canada and elsewhere.

Moniz has found that a lot of what the Roosevelt Project is trying to do is being reflected in legislation. For example, tax incentives in the Inflation Reduction Act (IRA) of 2022 are tied to boosting so-called "energy communities," vulnerable regions that, Moniz says, "have every reason to be concerned about their position in the transition" to clean energy.

The IRA also promotes the concept of hubs and clusters for strategic carbon dioxide transport and storage infrastructure. Given the large regional variations inherent in energy transitions—Detroit isn't facing the same problems as Baton Rouge—such place-based initiatives couple well with the Roosevelt Project approach, he notes.

Knittel says, "We provide the data to the stakeholders. And the stakeholders decide whether or not the benefits of doing these activities outweigh the cost."

He has reason for optimism: "If you provide objective data," he says, "policymakers do potentially change their opinions." —Deborah Halber

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The Next Quantum Revolution

MIT has long been a pioneer of quantum technologies. Now, Quantum@MIT is setting the stage for a new era.

In quantum science and engineering, researchers seek to understand and leverage quantum mechanics—the rules originally developed to describe the behavior of subatomic particles—and apply them to real-world devices. In what's considered the first quantum revolution of the 20th century, scientists observed quantum properties that enabled development of technologies such as lasers, the transistor, magnetic resonance imaging, and semiconductors.

The second quantum revolution is happening right now. Experts at MIT are poised to move from observation to actualization, realizing new quantum technologies that change the game in a wide range of fields.

"One of the aspects that I find most rewarding in quantum science and technology research is the strong link between fundamental research and its potential applications," says Paola Cappellaro PhD '06, the Ford Professor of Engineering, professor of nuclear science and engineering and physics, and leader of the MIT Quantum Engineering Group. "Fundamental advances in understanding quantum information and in developing novel technology and materials have led to remarkable achievements at a pace that I would have not anticipated when I began my doctoral studies."

Cappellaro directs Quantum@MIT, a new effort bringing together quantum-related programs to bridge fundamental discovery and impactful technology. As the field evolves and branches into more widespread applications, she says, a unified approach is needed in both research and education. "A key priority of Quantum@MIT will be to consolidate existing educational offerings, fill gaps, and broaden their appeal to a larger set of students, in light of the need for both a quantum-industry workforce and a quantum-savvy workforce in other sectors," she says.

This effort, she says, is critical to MIT's continued leadership in quantum research and to further the development of transformative quantum technologies and devices. Researchers at MIT, including at the MIT Lincoln Laboratory, a vital partner that is addressing multiple aspects of quantum research, are poised to take on the challenge. "To truly achieve the full power of quantum devices, in particular quantum computers, we still need the further breakthroughs that will happen only with a continued investment in basic research," she says. The following showcases just a few examples of how MIT researchers are leading quantum research—and where we're headed in the next quantum revolution.

Sensing

Quantum sensing collects data with quantum systems—highly accurate sensors are the most realized quantum technology at work today, facilitating advances in navigation, bioimaging, and materials such as batteries.

Diamond in the rough

Quantum spins in diamond are an excellent platform for sensing, reaching sensitivities and spatial resolutions that cannot be matched by more conventional, "classical" technologies. Guoqing Wang PhD '23 seeks new discoveries on the use of diamond spin as quantum sensors. "Our next step is to dig more deeply into the physics to better understand the underlying physical mechanism," he says. "With this knowledge, we hope to explore more quantum simulation and sensing ideas, such as simulating interesting quantum hydrodynamics and even transporting quantum information between different spin defects."

ILLUSTRATION: ARIEL DAVIS

Quantum simulation

Wolfgang Ketterle, the John D. MacArthur Professor of physics, received the 2001 Nobel Prize in physics for producing a Bose-Einstein condensate (the fifth state of matter obtained when gas particles are cooled to almost absolute zero). This achievement, which has led to advancements in precision measurement and sensing technologies as well as the development of atom lasers, laid the groundwork for quantum simulation as well. These simulations — exponentially more accurate than current computational models — have the potential to become a proving ground for new materials or chemistry, for example, that will lead to yet-unseen technological innovation in fields such as medicine and climate change.

Cold atoms control

A stalwart pillar for quantum progress, the MIT-Harvard Center for Ultracold Atoms works to enable greater control and programmability of quantum-entangled systems of low-temperature atoms and molecules. Researchers experiment with quantum gases of atoms and molecules to discover potential for new applications in measurement, sensing, and networking, seeking to measure and control the behavior of atoms. Using quantum simulations makes this work possible — and in turn, much of the resulting research improves the process of quantum simulation itself.

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IN A NEW LIGHT

Read more about Sahil Pontula '23, a PhD student in electrical engineering and computer science, who is researching ways to generate sources of macroscopic quantum states of light.

betterworld.mit.edu/spectrum/sahil

Quantum information processing

"Quantum advantage," a key factor in the evolution of the field, refers to cases in which quantum computers can perform calculations beyond the capacity of our current computers. As quantum devices become more sophisticated, that advantage broadens. MIT researchers like physics professor Aram Harrow '01, PhD '05 are drawing from different areas of quantum studies to expand and improve quantum advantage, including the exploration of communication complexity and quantum algorithms to help understand the scaling of entanglement in many-body quantum systems.

A pioneer of quantum engineering

The MIT Center for Quantum Engineering (CQE) is one of only a handful of quantum engineering programs in the world, bridging computer science, mathematics, natural sciences, and engineering. William D. Oliver, the Henry Ellis Warren Professor of electrical engineering and professor of physics, directs the CQE. "This new discipline is quintessentially MIT, deeply rooted in both science and engineering," he says. "As part of the broader Quantum@MIT, the CQE and its industry membership group engage researchers across the Institute to define quantum engineering, accelerating practical application of quantum technologies for the betterment of humankind."

Secure communication

In telecommunications, electronic devices known as repeaters receive a signal and transmit it. Quantum sensing and computing elements need to communicate with each other over distances ranging from 10 micrometers — about the size of a human hair — to hundreds of kilometers, all while maintaining quantum coherence. Researchers are successfully using quantum repeaters to develop longer-distance, secure transfer of information. In fact, MIT, Harvard, and Lincoln Laboratory have used optical fiber to connect the three campuses over a distance of 43 kilometers.

Superconducting quantum computers

The Cecil and Ida Green Professor in Physics Pablo Jarillo Herrero and his research team discovered the "magic angle" that turns one-atom-wide graphene sheets into either insulators or superconductors, and they continue to innovate with this uniquely powerful material. The group's recent findings could serve as a blueprint for designing practical, room-temperature superconductors, which could make quantum computing more accessible.

Climate

Quantum computing may greatly improve simulations leading to new chemistry or materials that could be used for climate solutions; examples include batteries, solar cells, and more efficient chemical reactions. Pervasive sensing facilitated by these computations will lead to better measurements, providing information about subtle shifts in our climate and the drivers of those changes.

New energy applications

Sahil Pontula '23, a PhD student in electrical engineering and computer science, researches the use of nonlinear and quantum optics to generate reliable sources of macroscopic quantum states of light, which could revolutionize existing quantum information and sensing platforms. He also has a passion for finding climate solutions, and he is working to harness the power of quantum optics and nanophotonics (a branch of nanotechnology) for energy applications such as enhanced batteries and devices that convert light to electricity.

Health care

The capabilities of quantum sensors continue to make rapid progress and hold near-term promise, particularly for biological applications.

Developing more effective drugs

Haoyang "Oscar" Wu, a doctoral candidate in the Department of Chemical Engineering and a Takeda Fellow, integrates quantum chemistry and deep-learning methods in his research to accelerate the process of small-molecule screening in the development of new drugs. Wu's research could help to transform and accelerate the drug-discovery process, offering new hope to patients and health care providers.

A quantum-ready workforce

MIT leads the effort to prepare students and professionals for the next quantum revolution: enrollment is open on MIT xPRO courses like Quantum Computing Fundamentals, a course designed for leaders of industry and government, and integrative measures through Quantum@MIT will create more interdisciplinary quantum programming. "Advancing the frontiers of research is just one part of the equation when it comes to quantum science and technology," says Cappellaro. "Equally critical is the development of a skilled workforce for the current and future quantum industry." —Joelle Carson

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LEARN MORE

Quantum Engineering Group: qeg.mit.edu

Center for Quantum Engineering: cqe.mit.edu

Better Cardiovascular Care through AI

Collin Stultz wants to help heart patients everywhere by applying machine-learning techniques to cardiovascular medicine

Although Collin Stultz, MD, loved math throughout high school and his undergraduate years, he headed to Harvard Medical School rather than pursuing pure mathematics, he jokes, to please his parents. Two years later, he began working toward a PhD in biophysics, completing his medical degree and doctorate in the same year. During his internship, residency, and fellowship at Brigham and Women's Hospital in Boston, Stultz was drawn to cardiology because, he says, "it's a very evidence-based field."

Stultz, now the Nina T. and Robert H. Rubin Professor in medical engineering and science and a professor in the Department of Electrical Engineering and Computer Science, joined MIT's faculty in 2004 and focused his early research on physical chemistry, investigating the proteins involved in various diseases. He showed, for instance, that when collagen—a protein linked to atherosclerosis—degrades and changes shape, it can lead to fatal heart attacks.

Pivoting to machine learning

Stultz, who is also codirector of the Harvard-MIT Program in Health Sciences and Technology and associate director of MIT's Institute for Medical Engineering and Science, shifted gears after realizing that the patients he was seeing would not derive near-term help from his basic research. Over a decade ago, he began investigating how patients with cardiovascular disease could benefit from machine-learning techniques, a class of methods in which computer algorithms search for inconspicuous relationships hidden amid large volumes of data. As he continues to explore this strategy, he sees greater potential, although he stresses that "machine learning is still in its nascent phases" in cardiovascular medicine.

One of the greatest opportunities for machine-learning methods lies in what Stultz calls the "sweet spot"—the group of people who fall in between the elderly patients known to have serious heart conditions and the young individuals with no family history of heart disease. In this group, he explains, only a small fraction will die of heart ailments any time soon, yet the total number of deaths will be highest because it constitutes the largest population.

"This is an important group to focus on," Stultz notes, and available data are sparse. But there are simple ways of gathering data that can tell us, he says, "whom in this cohort we should focus on and whom we don't have to worry about." Smartphones, for example, can monitor the number of steps one takes in a day; smartwatches and other wearable devices can measure the electrical activity of the heart in the form of an electrocardiogram (ECG). "Data from these devices contain a lot of information," Stultz said. "For example, knowing how your heart rate changes with exercise has been shown to be a strong predictor of cardiovascular health." While the heart rate is just the number of beats per minute, "the ECG can tell you what is going on within each beat, such as whether the heart is getting enough oxygen," he added. "With the aid of machine-learning algorithms, we can detect subtle changes in the ECG signal that are imperceptible to the human eye." By making use of strategies like this, he envisions that trips to a physician will become relatively rare—and hospital visits even rarer.

Tracking health threats with algorithms

His research team has recently trained algorithms that can predict pressures inside the left atria of patients with heart failure; as pressure goes up, the threat of congestive heart failure rises. This method is potentially an alternative to the current practice of threading a catheter into the heart, an invasive and sometimes risky procedure. Preliminary results indicate that these AI-abetted predictions were astoundingly good—almost 90% accurate. Clinical trials aimed at validating these results are underway at both the Massachusetts General Hospital (MGH), where Stultz practices cardiology, and at the Boston Medical Center.

Stultz is optimistic that this is just the beginning. "Machine learning will bring more equitable and fairer care for everyone," he says. "What we want to do, at a high level, is move the hospital to the home setting. If we can help each patient, regardless of their background or where they reside, get the same level of care that a patient at a tertiary care center like MGH receives, then we will be closer to realizing excellent and unbiased care for all patients with cardiovascular disease."

—Steve Nadis

PHOTO: SIMON SIMARD

Researchers use computer vision machine-learning tools to learn about the behavior of the nematode *C. elegans*.

PHOTO: COURTESY OF STEVEN FLAVELL

Worms + Math = New Insights Into Brains and Behaviors

Neuroscientist Steven Flavell and mathematics PhD students—with the help of a team of nematodes—zero in on the link between neural activity and how creatures act

MIT neuroscientist Steven Flavell hopes that a very small worm can shed light on a big question: How do neural circuits generate a creature's behavior?

Flavell studies the brain's internal states—partially hidden variables that shape perception, cognition, and action. An internal state such as sadness or joy represents neuronal activity on multiple levels. To fully understand the infinitely complex brain–behavior link, these levels need to be captured from the first inkling of a feeling to shedding a tear or laughing out loud.

"If we could obtain a predictive understanding of how all the brain's wiring gives rise to its activity dynamics and an animal's behavior, then we'd be able to make very strong predictions about the neural pathways that control internal states in the brain," says Flavell, associate professor of brain and cognitive sciences at The Picower Institute for Learning and Memory at MIT. "They would open the door to eventually designing rational approaches to change circuit activity and behavior."

Such an understanding could one day inform AI or help temper disruptive thoughts in patients with schizophrenia or other disorders, Flavell says. Diagnosing and treating psychiatric diseases with overlapping symptoms can be challenging, leading to a frustrating process of trial and error for physicians and patients. It's increasingly apparent that neural circuit dysfunctions underlie many common brain disorders, so the need for neural circuit-based therapies is vast.

A *C. elegans* approach to a complex subject

Flavell works with the nematode *C. elegans*, whose simple nervous system is more manageable for scientists to study than the millions of individual neurons in a mouse brain. While researchers had previously mapped each of the roundworm's 302 neurons, they had only a general idea of which sets of neurons activate internal states such as hunger, the drive to reproduce, and others.

Flavell's lab built a microscope using AI-powered robotics that tracks and records the one-millimeter-long, transparent worms as they move freely around a glass plate. "We can see the inside of its mouth moving as its chews. We can measure everything the animal is doing," such as wriggling like a sine wave, laying eggs, or foraging for food. "We then use computer vision—machine-learning tools—to extract all the behavioral parameters of the worm over time," he says.

A second microscope under the glass plate captures the green glow of proteins engineered to fluoresce when a neuron is active.

The result is a mountain of raw data. That's where MIT applied mathematics PhD students Alexander E. Cohen and Alasdair D. Hastewell '18 come in.

The mathematics of behavior

Cohen is pursuing a PhD in chemical engineering and computational science and engineering and Hastewell in applied mathematics. They developed tools that compress data representing more than 100 points on the worm's body into around five key parameters. "We represent all that high-dimensional behavioral data in a more compact, usable form," Cohen says.

"There are different behaviors the worm will exhibit, and types of shapes" that correspond with those behaviors, he says. "The dynamics between the shapes and one set of behaviors will be different than a new set of behaviors. Hopefully, a lower-dimensional representation will allow us to study those different behaviors more easily."

The output, Hastewell says, is a grid of numbers that "enables us to use tools from mathematics to understand those behaviors in a way that you can't do if you just have a movie of a worm."

Cohen and Hastewell found that shape dynamics—specifically, the undulatory locomotion of not just worms, but also centipedes and snakes—are governed by Schrödinger equations, the fundamental basis of quantum physics. Applied to biological systems, the Schrödinger equation can help characterize and predict the roundworm's behavioral dynamics.

Flavell says, "It's cool to interact with Alexander, Alasdair, and [their advisor, MathWorks Professor of Mathematics] Jörn Dunkel, who have these amazing skills and models and tools that are not typically applied in neuroscience."

In a study published in *Cell* in 2023, Flavell determined that around a third of the worm's nervous system can flexibly encode different behaviors under different circumstances, allowing the animal to adapt to a constantly changing environment.

Now, with the latest log of the worms' brain-wide activity, the researchers' goal is to translate the visual data into predictive and interpretable models documenting a full set of causal interactions between neurons and behavior.

Down the road, researchers hope to illuminate brain–behavior links in other model animals, such as zebra fish or fruit flies.

"I can see, in future years, applying these same methods to more complex animals, humans, and disease states," Hastewell says. —Deborah Halber

What's Next?

How Will We Make Things?

Three ways MIT researchers are defining the next generation of manufacturing

“If you want to know if a robot can do a task, you have to ask yourself if you can do it with oven mitts on,” says Julie Shah.

Manufacturing is undergoing a dynamic evolution. According to John Hart SM ’02, PhD ’06, who heads MIT’s Department of Mechanical Engineering, the processes of making everyday objects are being dramatically enhanced by the introduction of digital technologies—and the possibilities for the future are boundless.

MIT, Hart says, has an outsized role to play in defining the next generation of manufacturing, leading the way through research, education, and entrepreneurship. A new effort, Manufacturing@MIT, which Hart codirects with Suzanne Berger, Institute Professor of Political Science, will develop new scalable and sustainable production processes and study how new technologies are adopted and how organizations can improve their factories while creating good jobs.

In the lab, Hart’s research involves a melding of centuries-old manufacturing know-how with more recent technologies like 3-D printing and robotics, and cutting-edge computing techniques, including AI. Take the jet engine, a machine that must operate safely and efficiently at high temperatures. What should its critical components be made from? In many cases, we’ve reached the performance limits of traditional materials, which limit the performance of sophisticated technologies.

“We need to figure out how to build components that combine the best of multiple materials in one,” says Hart. With today’s 3-D metal printers, “it’s only possible to print one alloy at a time.” Hart, however, developed a new kind of 3-D printer that varies the composition of the material voxel by voxel, throughout the printed object. (A voxel is like a pixel but in three dimensions instead of two.)

First, an inkjet head lays down a set of special inks, each with a different mix of metal or ceramic nanoparticles. A fine metallic powder is then deposited. Then, a laser melts the powder and mixes the ink, and this process repeats for each layer, ultimately forming the final object.

For a jet engine component, this process will allow Hart to print an outer layer that’s resistant to oxidation, an interior that can handle high stress, and a gradient between them. The technique blends the materials together, like a bone that smoothly transitions between its harder and softer portions. In fact, Hart says this technology could be used to create better medical implants like artificial hips or vertebrae that integrate more favorably within the body. The vision for the next wave of 3-D printing, he says, “is the ability to specify the material properties anywhere within an object. And we need to develop the design and computation tools to usher in a new era of product innovation.”

AI to navigate a world of design choices

“Can AI come up with a product we’ve never thought about?” asks Faez Ahmed, the American Bureau of Shipping Career Development Professor of mechanical engineering, who leads MIT’s Design Computation and Digital Engineering lab. “Can it get a patent?”

Ahmed is trying to create generative AI algorithms to do just that. He considers a bicycle. When it comes to manufacturing, he says, “most people just take the default bike and make small modifications.” How does one navigate such a vast design space to make something new?

Ahmed’s answer is an “AI copilot.” He likens it to J.A.R.V.I.S., the AI assistant in the *Ironman* movies—a technology that could help brainstorm ideas, field questions about the production process, and show how to improve on everything that’s come before.

It’s a system that simulates real-world physics, incorporates manufacturing constraints, and draws on thousands of actual products to respond to requests such as: “I want a futuristic cyberpunk-style road racer.” The results are ready-to-be-built designs that no one has seen before.

Ahmed is excited by the potential of tools like this one to democratize design. “There are people across the world with good ideas,” he says, “but they’re not necessarily trained in engineering software.” His hope is that his tools may one day reduce the barrier of entry to get people of all backgrounds started.

The goal, he says, is “to augment human potential, not replace it.”

More agile robots on the factory floor

Julie Shah ’04, SM ’06, PhD ’11, the H. N. Slater Professor in Aeronautics and Astronautics, adopts a similar philosophy in her work on robotics.

The traditional difference between people and robots on a factory floor is their flexibility, according to Shah, who leads the Interactive Robotics Group in the Computer Science and Artificial Intelligence Lab. Coordination of human tasks happens organically, with the reassigning of tasks as needed. But introduce a robot, and that portion of the manufacturing process tends to become more rigid. Shah also serves as faculty director of the MIT Industrial Performance Center and co-leader of its Work of the Future Initiative, which carries out an applied research and educational program to understand how organizations make new technologies work in practice.

“If you want to know if a robot can do a task,” she says, “you have to ask yourself if you can do it with oven mitts on.” But so much of the work we do in our lives, including in manufacturing, requires dexterity and adaptability, and getting a robot to help with nimbler tasks is costly. According to Shah, it’s one of the reasons that only 1 in 10 manufacturers in the United States has a robot, and why those who have them don’t tend to use them much.

Shah is trying to change that by designing robots and automation systems that are safe, smart, and flexible. Done properly, she says, human-robot integration in some cases has led to better-paying jobs, workers learning new skills, and higher profits and productivity.

Part of her work involves programming robots to model how people move and operate so they can better integrate into an industrial environment alongside their human companions. Crucially, she’s also designing robots that workers on the factory floor can program and test without needing special expertise. That means affordable, more agile machines (think no oven mitts) that are just as easy to teach and train as a human being—“a system that you can program with low-code or no-code interfaces,” she says.

Shah conjures an example of someone wearing a mixed-reality headset while they walk and talk through the steps of an industrial process. That visual and verbal information would be automatically compiled into a control program “and then the robot just does it,” she says. The goal is to put the front line workers into the driver’s seat for testing, deploying, and re-programming robots as the work changes. “That’s the dream of the future.” —Ari Daniel

PHOTO: OPT LASERS / UNSPLASH

Weaving a Web of Textile Research

Fabric Innovation Hub aims for sustainable clothing manufacturing

In the summer of 2023, PhD student Irmandy Wicaksono used a weave of recycled polyester yarn and conductive yarn sensors (above) to build the Living Network Pavilion—a large-scale tent structure with lighting and visual patterns that respond in real time to human movement and sunlight—at Burning Man, an annual gathering of innovators and artists held in the Nevada desert.

PHOTOS: COURTESY OF IRMANDY WICAKSONO

In the middle of her third year as a mechanical engineering student at MIT, Julia Chatterjee '22 signed up for an Independent Activities Period course in textile design. In the four-week class, she and fellow MIT students partnered with students at the Fashion Institute of Technology in New York City to solve a sustainability problem in clothing manufacturing.

"I was always interested in fashion and in making clothes," says Chatterjee, who currently works in San Francisco at Refiberd, a company developing intelligent sorting technology for textile-to-textile recycling. "But when I arrived at MIT, it didn't look like there was a lot going on with textiles. The picture looked very different by the time I graduated."

"There have always been a lot of exciting ideas in textile research on campus," says Gregory Rutledge PhD '90, the Lammot duPont Professor in Chemical Engineering. He leads MIT's Fabric Innovation Hub, a network of MIT faculty, students, and industry thought leaders created to promote promising ideas and technologies from MIT laboratories that can help revolutionize the textile industry.

"So many great ideas at MIT are born when someone from one department shares their work with someone from another department, but we weren't doing that in textiles," Rutledge says. "I realized we needed a way to connect across disciplines, and to identify ourselves for the outside world."

Surveying the landscape

A loose weave of researchers, students, and textile professionals, the Fabric Innovation Hub has grown organically and gradually. A particularly significant year was 2017, when Maria Zuber, MIT's vice president for research, appointed Rutledge to coordinate MIT's engagement with Advanced Functional Fabrics of America as it opened a new prototyping facility just off the MIT campus. "Much of my role was to go around campus to discover what people were doing in this space," says Rutledge. "To find out who was ready to translate their research into production, and to help find them industry partners."

Soon afterward, Rutledge and his colleagues built a website to showcase MIT textile researchers and their work, then organized a series of activities and projects both across and beyond campus. Events have included a sustainable footwear summit and a workshop on campus that was coordinated with the joint meeting of the Sustainable Apparel Coalition and the Global Fashion Agenda that took place in Boston in 2023.

Industry-wide challenges

Textiles—the oldest human industry—faces multiple challenges today. Perhaps the most pressing issue is sustainability. Collectively, textile manufacturing produces over four billion metric tons of carbon dioxide equivalent each year, more than the aviation and maritime shipping industries combined. The industry relies on close to 97% virgin feedstock, and it recycles or downcycles less than 15% of its production. The average garment is worn just seven times before it ends up in a landfill.

Researchers in departments across MIT are busy developing technologies to reduce industry carbon emissions. Bradley Olsen ’03, the Alexander and I. Michael Kasser Professor of chemical engineering, and Kristala Prather ’94, the Arthur Dehon Little Professor and head of the Department of Chemical Engineering, are working to identify bio-based monomers for the synthesis of new polyesters that are degradable at the end of the fabric’s lifecycle. In the Department of Mechanical Engineering, principal research scientist Svetlana Boriskina is perfecting a method to make garments from polyethylene.

“The idea was that instead of cooling rooms or buildings, we might try to cool the bodies in those buildings,” says Boriskina, who came to MIT as a postdoctoral researcher in 2012. “For that, we needed a fiber that allowed heat to escape. Polyethylene does that, but it was hydrophobic—it wouldn’t wick moisture. And according to the industry, you couldn’t dye it. We found a way to make it do both. Our environmental analysis of the entire process showed that it had a smaller impact than any other fiber, natural or synthetic.”

From smart wearables to architectural textiles

Part of the Fabric Innovation Hub’s activity is to devise ways to add value to textiles—designing products that people will not readily throw away. One way to do that is through smart textiles, ranging from garments that sense bodily movement and vital signs to drapery that harnesses the energy in sunlight instead of merely blocking it. “If electronics or sensors are becoming more compact, soft, and fiber-like, they can be integrated seamlessly into textiles such as clothing, carpets, interior textiles like curtains and furniture fabrics, or even on a larger scale, as architectural textiles,” says Irmandy Wicaksono SM ’19, a doctoral candidate at the MIT Media Lab.

The human factor

The Fabric Innovation Hub has already yielded viable ideas ready for translation into industry. MIT’s Self-Assembly Lab is collaborating with the MIT-born apparel company Ministry of Supply on a series of smart textiles that change shape and structure in response to heat and moisture. Boriskina works with the US Navy, US Army, medical apparel company Colorchain, and automotive company Seoyon E-Hwa to engineer thermoregulating textile products from the smart polyethylene fiber she developed.

“Our goal is to build a network of knowledge in service of the textile industry,” says Yuly Fuentes-Medel, manager at the Fabric Innovation Hub. Trained as a biochemist at the University of Concepcion in her native Chile, Fuentes-Medel was instrumental in drafting a white paper titled the Footwear Manifesto that outlined strategies to reduce waste in the shoe industry. “We want to support the industry as it faces the challenges of a circular economy, new financial models, and decarbonization. At the Fabric Innovation Hub, we invent, educate, and connect.”

Rutledge believes MIT’s greatest contribution to the textile industry may be its graduates. “Industry can do certain types of research,” he observes. “But we produce smart and educated students for an industry that needs smart and creative people, people who could literally transform the industry. Only an academic institution like ours can do that. I see that when I attend industry conferences. People in the profession know there are problems to solve, and they think that if anyone can solve them, it’s going to be MIT students.” —Ken Shulman

Left: The Living Network Pavilion was a dodecagonal pyramid, 18 feet high and 26 feet wide. Its optically and electrically active yarns (above) sense activities and dynamically change color and light up through the day and night.

A Vision for Computing Research and Teaching Realized

As its new home opens, a look at the ongoing impact of the Schwarzman College of Computing

The MIT Stephen A. Schwarzman College of Computing opened its new building this winter, following a $1B commitment from MIT in 2018 made possible by a $350M gift from philanthropist Stephen A. Schwarzman. The college's goal: to transform computing research and education—advancing core computer science and AI; infusing computing with disciplines across MIT; and taking into account the social, ethical, and policy dimensions of computing.

As innovations in hardware, software, algorithms, and AI redefine our approach to problem-solving in nearly every field, the MIT Schwarzman College of Computing is fulfilling its mission across campus from its brand-new home (see page 2). It is accelerating research and teaching in the core areas of computer science and AI and educating "bilinguals" who combine a command of computing with scholarship across a broad array of disciplines. At the same time, the college is engaging head-on with the social, ethical, and policy issues that accompany the rise of AI.

"In just a handful of years, the Schwarzman College of Computing has become an essential part of the Institute as it shapes the future of computing, driven by the vision, dedication, and contributions of hundreds of passionate members of MIT's faculty, students, and staff," says Daniel P. Huttenlocher SM '84, PhD '88, dean of the college and the Henry Ellis Warren Professor of Electrical Engineering and Computer Science.

"The recent surge in generative AI underscores the importance of all three aspects of the college's mission: to advance core computing, infuse the forefront of computing with other disciplines, and attention to social, ethical, and policy aspects of computing."

DEAN DANIEL P. HUTTENLOCHER

19

departments and programs offering Common Ground classes

159

students have been SERC Scholars

INNOVATIONS IN EDUCATION

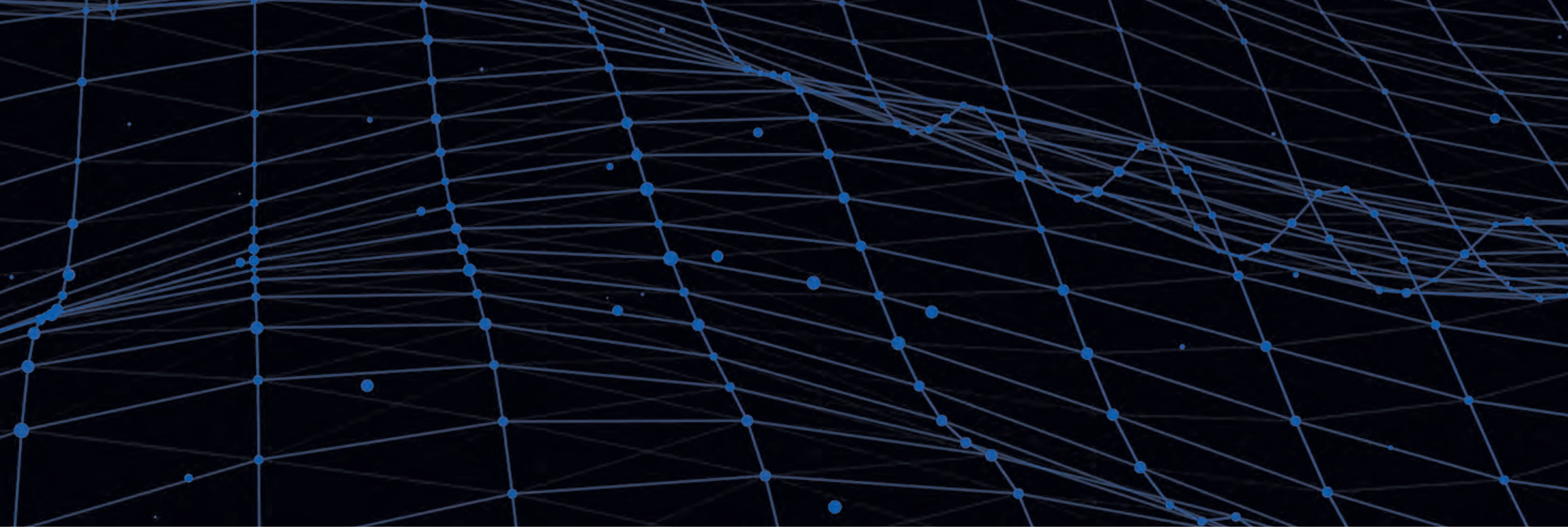
Over the past decade, MIT has seen an explosion of interest in coding, algorithms, and AI from students seeking mastery of these topics. At the same time, employers increasingly have their eye on those with this expertise as well as individuals that can understand key challenges in specific domains and bring the forefront computing ideas and practices to bear on them. The college has built a one-of-a-kind academic platform to address these needs.

The college's Common Ground for Computing Education facilitates coordinated computing education across the Institute, bringing multiple departments together to develop and teach new classes that can be the foundations of new programs. Some Common Ground subjects, such as Modeling with Machine Learning: from Algorithms to Applications, include a common core and discipline-specific material taught in parallel while others involve classes centered around computational thinking in the context of other disciplines.

Meanwhile, four blended computing majors at MIT are offered by the Department of Electrical Engineering and Computer Science (EECS) — part of the college and the School of Engineering — each of which brings together computer science and AI with another major in the schools of Architecture and Planning; Humanities, Arts, and Social Sciences; and Science. These majors now encompass some 360 undergraduates, or roughly 8% of MIT's total undergraduate enrollment.

"You can't just think of the world through one lens," says Nikasha Patel '22, who earned an SB and MEng in Course 6-9 Computation and Cognition (offered with the Department of Brain and Cognitive Sciences) and is pursuing a PhD at MIT, where she is using AI to build a computational model of how infants learn to walk, which could help robots acquire motor skills. "You need to have both perspectives so you can tackle complex problems together."

In fall 2023, the Center for Computational



Science and Engineering, an academic unit in the college, also introduced a new standalone PhD degree program that will greatly enhance MIT's graduate education in computing. There is also a planned MicroMasters in Artificial Intelligence and Decision Making that will expand the number of people who can access high-quality education in this exciting area.

SOCIETAL IMPLICATIONS

Social and Ethical Responsibilities of Computing (SERC) is one of the pillars of the college, bringing engineers and computer scientists together with social scientists and humanists to assess computing challenges and opportunities through teaching in stand-alone classes and embedded content; research, including through the recently launched seed grants, and other engagements such as the SERC Scholars program (see story on page 16).

Asu Ozdaglar SM '98, PhD '03, deputy dean of academics for the college, head of the Department of Electrical Engineering and Computer Science, and MathWorks Professor of Electrical Engineering and Computer Science, moderated a panel at the college's inaugural SERC Symposium in 2023 and summed up the current computing landscape: "While the promise is evident to all of us, there's a lot to be concerned about as well. This is very much the time for imaginative thinking and careful deliberation to improve the algorithms of tomorrow."

Developing recommendations for technologically informed regulatory frameworks and policy-aware technological development is also front of mind for the college. The AI Policy Forum, in 2021 and 2022, facilitated working groups and events aimed at engagement between policymakers and academics. More recently, the college and the MIT Washington Office spearheaded AI Policy Briefs, a resource for US policymakers to shape the discussion on governing AI amid heightened interest and considerable new industry investment in the field.

FACULTY FOR TODAY AND TOMORROW

The college is working toward a goal of increasing MIT's academic capacity in computing and AI by 50 positions, divided between core faculty in EECS and shared hires with departments across MIT—researchers deeply grounded in their discipline and with expertise in frontier computing methods. These exceptional new talents have been recruited against top programs and from industry. They chose MIT for the dynamic and broad computing community the college has helped foster.

READ MORE ABOUT THE COLLEGE'S NEW FACULTY AT
`betterworld.mit.edu/spectrum/college`

BROADENING THE TALENT BASE

A focus of the college is on bridging the talent gap in computing fields for women and underrepresented groups. Break Through Tech AI, hosted with the national coalition Break Through Tech, enrolled 73 Boston-area undergraduates in fall 2023 to learn the basics of AI and machine learning and apply their skills to real-world industry projects.

In a similar vein, EECS launched Thriving Stars in 2021 to close the gender gap in MIT's largest doctoral program. Nationwide, less than a quarter of doctoral candidates in electrical engineering and computer science are women.

Thriving Stars supports women graduate students in EECS through every step of their PhD journey, offering help in navigating the application process, while showcasing research opportunities, interdisciplinary collaborations, internships, and job openings. In its first 18 months, Thriving Stars had helped break records in EECS. Female applicants in the 2023 graduate admissions cycle reached 830, an all-time high.

40

faculty hires since 2019,

26 of them in new positions created with the founding of the college

18

departments have participated in faculty searches across MIT

45%

women faculty hires in the college

Economics Research to Change the World

New fundraising effort keeps MIT Department of Economics at the vanguard of an evolving field

In the field of economics, few institutions have had as profound an impact or been home to as many influential scholars as MIT. A new fundraising initiative for the Department of Economics led by Roger Altman, former chair of the MIT Economics Visiting Committee and life member emeritus of the MIT Corporation, seeks to take the department into a new era of achievement, fostering innovative research that addresses national and global challenges. Launched in 2023, the initiative is almost halfway to its $60 million goal.

"MIT has managed to be one of the best economics departments in the country while existing in the middle of a science and engineering school," says Altman. "It's a rare accomplishment."

"Roger has been amazing in terms of his leadership, his giving, and his encouragement of others in their philanthropy," says Jonathan Gruber '87, Ford Professor of Economics and department head. Altman, cofounder and senior chairman of the investment firm Evercore and a long-time champion of MIT economics, is supporting the initiative with a gift from the Altman Family Fund to launch the Economics Predoctoral Program and to support faculty research.

Other major contributions include gifts to establish the Daniel and Gail Rubinfeld Professorship Fund in Economics, the Thapanee Sirivadhanabhakdi Techajareonvikul Professorship Fund established by economics undergraduate alumna and her husband, Aswin Techajareonvkul MBA '02; the Locher Economics Fund for faculty research established by Kurt '88, SM '89 and Anne Stark Locher; the Dr. James A. Berkovec Memorial Faculty Research Fund in Economics, created by Ben Golub '78, SM '82, PhD '84, and another endowed professorship in the department; and individual gifts from many other generous friends and alumni.

Predoctoral fellowships key for aspiring graduate students

As Gruber explains, the field of economics has undergone significant changes in recent decades, due in large part to the massive increase of available data. While this is a boon for innovative research, he says, "it's incredibly intensive because you're working with gigabytes and terabytes of data." Expanded research teams can help to process such abundant data and use rigorous, empirical methodology to explore complex issues. "This is 'big lab' science," says Gruber, "and it requires a lot of people working together. That's where predocs can make a big difference."

Predoctoral fellowships are designed for college graduates who plan to apply to graduate school. "It's an incredible match," says Gruber. While the highly motivated predoctoral students gain the experience and mentorship needed for graduate-level work, their MIT mentors get additional team members to help with labor-intensive research projects. The Economics Predoctoral Program will enable six junior faculty members to each hire a predoctoral fellow this year, with plans to fund up to 24 positions in the long run.

Research rooted in key global issues

Economics research may often be anchored in financial data, but the field looks far beyond money to understand people, communities, and the interactions of human society and the planet.

"We have research that is changing the world," says Gruber, pointing to the example of the groundbreaking antipoverty work of the department's Abdul Latif Jameel Poverty Action Lab (J-PAL), a global research center anchored at MIT. "If you look at the research that J-PAL has done and the government policies that are based on that research, they've impacted the lives of 600 million people around the world."

Gruber points to several consequential areas of economic research at MIT: the impact of artificial intelligence on the labor market and labor policy; preparing the existing long-term care infrastructure to serve an aging US population; and strategies to help countries at all stages of development cope with climate change. "These are all first-order questions that speak to social and economic issues that need to be tackled," he says. "Roger and the other generous individuals who are supporting this initiative are bringing us closer to that."

Altman notes that his own enthusiastic support of MIT's Department of Economics stems from his interactions with economists while serving in the US Department of the Treasury during the Carter and Clinton administrations. "I have a longstanding serious interest in public policy as it intersects with economics."

Altman has every confidence that philanthropic support of MIT economics faculty, students, and the new predoctoral program is worthwhile. "Every time I'm on the campus, I'm awed by the faculty and students that I interact with even briefly. MIT is just an extraordinary collection of talent and motivation." —Kris Willcox

Tobias Salz (left), the Castle Krob Career Development Associate Professor of Economics, is working with economics predoctoral research fellow Wonjoon Choi PhD '12 on a large project on the search engine market. Their collaboration is part of a pilot of the new predoctoral program. Choi has been "instrumental in many parts of the project, including the design of an experiment and data analysis," says Salz.

PHOTO: JON SACHS

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Combining Tech and Finance to Power Clean Energy

Shu Yang Zhang '24 plots a course for impact with a double major in materials science and engineering and finance

As a public high school student in Northern California, Shu Yang Zhang '24 learned about MIT from an enthusiastic chemistry teacher and soon made it her top college choice. Zhang reflects that she was drawn to the Institute by the promise of exciting research and brilliant people, but also by the emphasis on collaboration. "I have definitely have not been disappointed," she says, citing the MIT community's "collective desire to learn and do something meaningful with the knowledge you have."

Zhang, a recipient of the Robert A. Laudise Memorial Fund scholarship, hopes to help society make great strides toward sustainability and clean energy. Recognizing a need for financial as well as technical expertise, she double majors in materials science and engineering and finance. Her curriculum includes coursework at the MIT Sloan School of Management.

To enable next-generation energy sources, she explains, it is critical to have both scientific knowledge and a firm understanding of the numbers involved. "Practical matters, like 'What kind of financing do I need to actually create this manufacturing line?'" Being a double major, she says, "gives me this other viewpoint into the up-and-coming materials in the sustainability and energy space."

Zhang applied this dual approach to choosing summer internships, seeking experience in both engineering and finance to help identify her ideal career choice. The summer after her first year at MIT, she interned at a hedge fund assisting with fund accounting, tax, and valuation. "From that I realized that I didn't want to be doing just the finance side," she says. "I was missing the stimulation from the science, the theoretical approach, all the things I love."

The following summer, she worked in field engineering at an electronic components supplier for electric vehicle (EV) projects. "It was a little bit of engineering because you do have to understand what this battery system looks like for a car, and it was also a lot of business: thinking about sales and strategy and how to approach customers in these different fields."

While she enjoyed working at the intersection of her two majors, this role "wasn't quite technical enough for me," she explains.

As an undergraduate researcher for Yet-Ming Chiang '80, ScD '85, the Kyocera Professor of Ceramics in the Department of Materials Science and Engineering, beginning in her junior year, Zhang developed a deep interest in lithium-ion and lithium metal batteries. In the summer of 2023 she put that experience to good use as a cell engineering intern at Tesla on its lithium extraction projects in Nevada. "Tesla was my dream company to work for," she says. "I got to think more deeply about the critical materials and minerals that go into EV batteries and the battery materials I've been developing at MIT."

Her experience in Chiang's group, combined with earlier work researching sustainable cement under the direction of Associate Dean of Engineering Elsa Olivetti PhD '07, the Jerry McAfee Professor in Engineering and codirector of the MIT Climate and Sustainability Consortium, contributed to Zhang's enthusiasm for materials science theory and convinced her that graduate school should be next. "I just feel like I'm not done learning," she says. Eventually, she envisions working in the clean energy industry, "working on large-scale projects that would get new battery materials or clean energy infrastructure into the hands of everyday people."

Impact, she says, is her driving force. "Even with great technology, if we can't get it into the hands of everyday people, it's not having much impact."

Zhang hopes her career will honor the legacy of Robert Laudise PhD '56, since the scholarship established in his name has made her undergraduate education possible. "Dr. Laudise dedicated his life to advancing the field of crystallography and materials science," she says. "Being funded by this very well-established materials scientist—as a materials science student, that connection was really meaningful to me. The funding has been pivotal, and I really appreciate that scholarships from generous donors lower the barriers to education."

"One of my favorite parts of being in the materials science community," Zhang remarks, "is working as a teaching assistant, helping younger materials scientists develop the interest and appreciation for materials. That's my way of making sure this funding is put to good use and helping the up-and-coming generation."

—Christine Thielman

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POSITIVE ENVIRONMENT

In spring 2024, a new center and showcase for environmental and climate research opened its doors on MIT's campus. The Tina and Hamid Moghadam Building connects with and enhances the iconic Cecil and Ida Green Building, creating new headquarters and a gateway entrance for three related departments: MIT's Department of Earth, Atmospheric and Planetary Sciences, MIT's Environmental Solutions Initiative, and the MIT-WHOI Joint Program in Oceanography/Applied Ocean Science and Engineering. As part of the project, the Green Building's primary lecture hall was renovated and improved. Together, the Moghadam and Green Buildings make for a new nexus of climate research, environmental innovation, and academic programs on campus. As part of the project, the Green Building's primary lecture hall was renovated, improved, and named after the first person to receive a geology degree at MIT in 1891—Dixie Lee Bryant.

PHOTO: ANN GREANEY-WILLIAMS

FOR A BETTER WORLD