Massachusetts Institute of Technology
Fall 2022

Spectrum

DESIGN

MIT System Design and Management graduate Jack Yao SM '18, founder of Mobile Pixels, Inc.—which sells monitor extension kits and other tools to help people work productively from anywhere—credits MIT with giving him the skills to launch his company and thrive through the pandemic.

PHOTO: BOB O'CONNOR

(↗)
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(↗)
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Fall 2022

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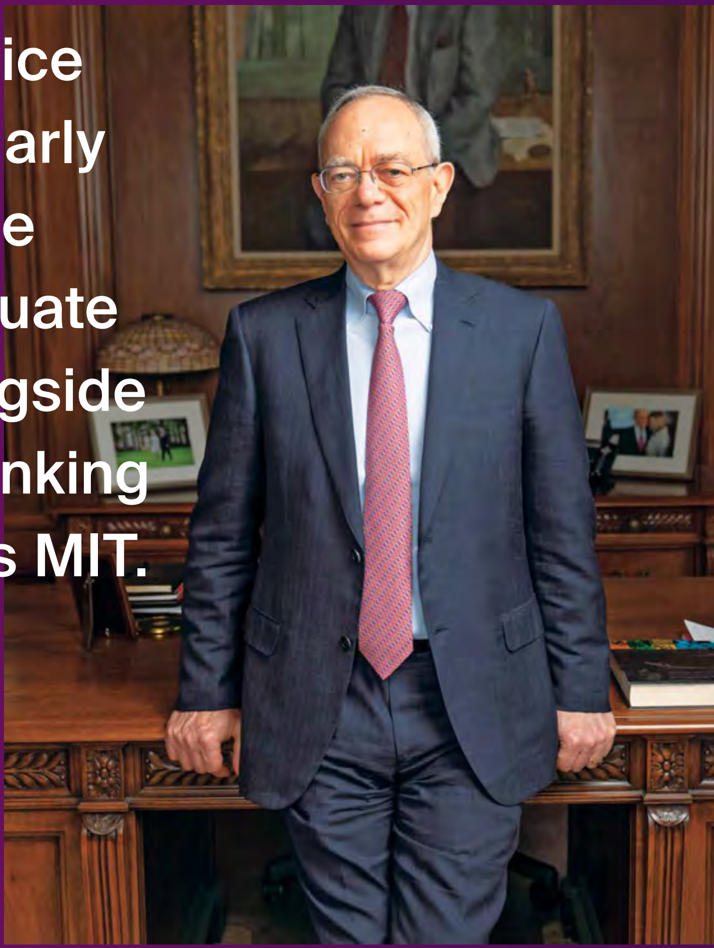
Community Highlights

FRONT COVER
Detail of a highly technical, bespoke textile developed by Faith Jones '22 to solve recyclability problems in the furniture design industry.

PHOTO: FAITH JONES

At MIT, we sometimes describe our work as "inventing the future." Beyond the Institute's technical, scientific, and analytical strengths, that assignment requires profound humanity and imagination—the capacity to listen closely and think broadly, to reframe old problems in unexpected ways, to crystallize bold new visions, to weave the wisdom of different disciplines and voices into fresh, humane solutions. These are essential strengths of design thinking.

As I come to the end of my service as MIT's president, it is particularly gratifying to know that—from the increasingly popular undergraduate design minor to the new Morningside Academy for Design—design thinking is coming into its own, all across MIT.



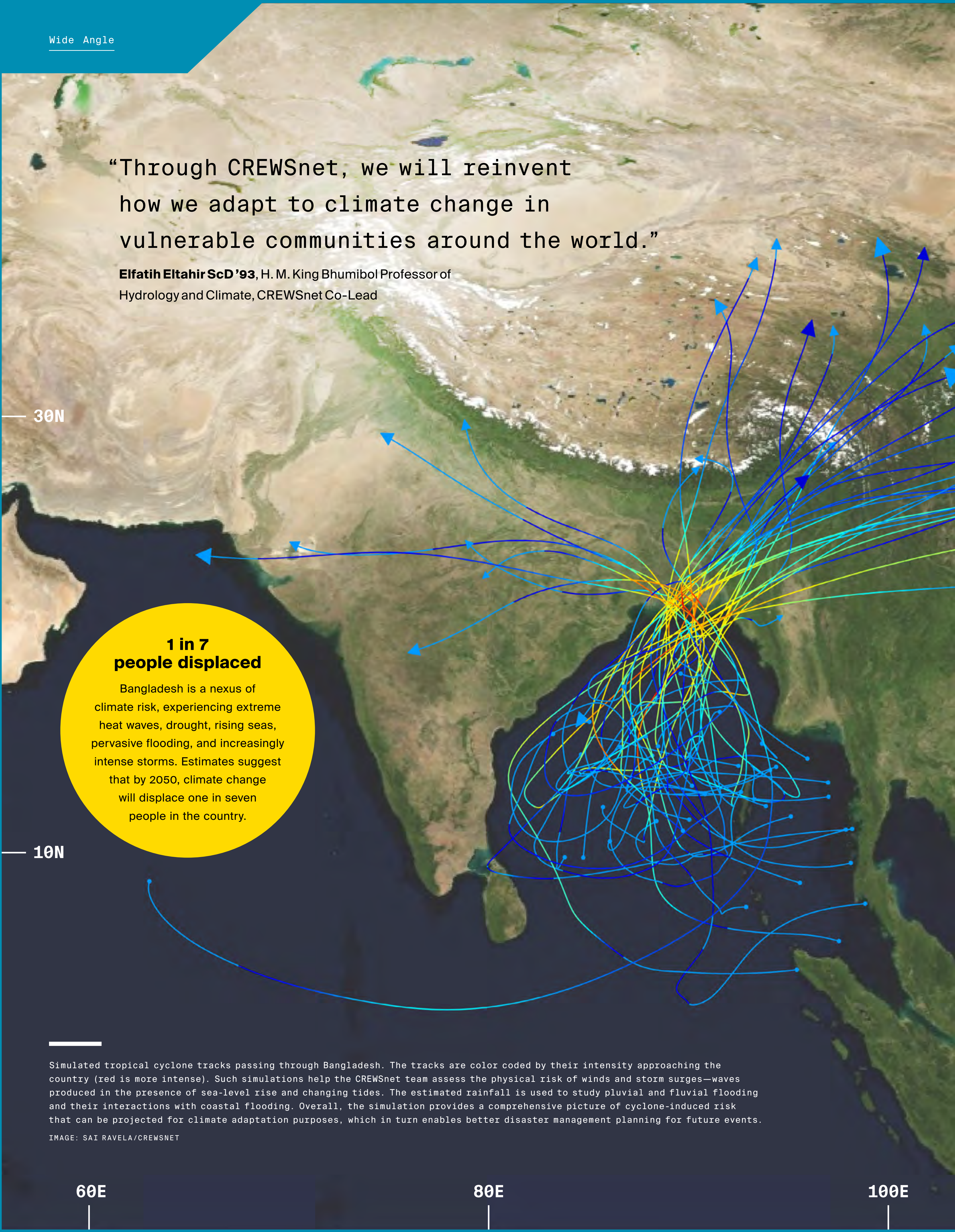
L. Rafael Reif
MIT President

> "Through CREWSnet, we will reinvent how we adapt to climate change in vulnerable communities around the world."

Elfatih Eltahir ScD '93, H. M. King Bhumibol Professor of Hydrology and Climate, CREWSnet Co-Lead

1 in 7 people displaced

Bangladesh is a nexus of climate risk, experiencing extreme heat waves, drought, rising seas, pervasive flooding, and increasingly intense storms. Estimates suggest that by 2050, climate change will displace one in seven people in the country.



Simulated tropical cyclone tracks passing through Bangladesh. The tracks are color coded by their intensity approaching the country (red is more intense). Such simulations help the CREWSnet team assess the physical risk of winds and storm surges—waves produced in the presence of sea-level rise and changing tides. The estimated rainfall is used to study pluvial and fluvial flooding and their interactions with coastal flooding. Overall, the simulation provides a comprehensive picture of cyclone-induced risk that can be projected for climate adaptation purposes, which in turn enables better disaster management planning for future events.

IMAGE: SAI RAVELA/CREWSNET

CREWSnet contributors at MIT include faculty and students from across the Institute, representing dozens of disciplines in science, engineering, and the humanities.

Five years

CREWSnet's five-year plan is to create and demonstrate proactive, integrated decision support tools and services that empower frontline communities to prepare for climate impacts and minimize losses.

Early Warning System for All

Across Bangladesh, climate change is a daily reality, reshaping everything from housing and crops to economic policy and social life. As in other climate-vulnerable regions, residents face urgent questions about the future: Should they attempt to relocate? Would it be better to stay and adapt? What resources are available to guide and support their decisions?

Such questions motivate CREWSnet (the Climate Resilience Early Warning System Network), a ground-breaking collaboration between MIT and Bangladesh-based global nonprofit BRAC. CREWSnet is one of five flagship projects chosen for support in 2022 through MIT's Climate Grand Challenges initiative.

According to Deborah Campbell, MIT Lincoln Laboratory's Climate Change Initiative co-lead and CREWSnet's executive director, "the project is empowering underserved communities by giving them the tools they need to interpret local risk, minimize loss, and plan for their futures." One example is the use of the "downscaling" approach—which provides climate variables at the resolution needed to assess climate change impacts at regional and local scales—described by Earth, Atmospheric and Planetary Sciences (EAPS) Emeritus Professor Kerry Emanuel '76, PhD '78 and EAPS Principal Research Scientist Sai Ravela. The approach simulates tropical cyclone tracks through Bangladesh (pictured) under various climate scenarios to assess wind, rainfall, storm surges, waves, and rainfall-driven flood inundation to advance our broader understanding of cyclone-induced physical risk.

Other tools include cutting-edge climate models developed by the research group of CREWSnet co-lead Elfatih Eltahir ScD '93, the H. M. King Bhumibol Professor of hydrology and climate in the Department of Civil and Environmental Engineering, and researchers at the MIT Center for Global Change Science; insights and recommendations from development economists at the Abdul Latif Jameel Poverty Action Lab; and proactive, integrated decision support tools for local communities and government agencies developed by the Humanitarian Assistance and Disaster Relief (HADR) Systems Group at Lincoln Laboratory.

John Aldridge, CREWSnet co-lead and associate leader of the HADR Systems Group, notes that CREWSnet and other MIT Climate Grand Challenges projects represent "the perfect opportunity to synthesize together MIT's strengths in climate science, impact modeling, and decision support systems" to solve complex and urgent climate challenges. —Kris Willcox

DESIGN

To put visionary ideas to work in the world requires intention and discipline—the essence of design. At MIT, focused design work runs the gamut from guiding the interactions of proteins to developing new ways to construct housing. By combining creativity, innovation, and synthesis to reveal new pathways forward, design draws mind and hand together, providing a strong foundation for efforts across the Institute to confront society's most complex challenges.

Samples of experimental, recycled high-density polyethylene material for furniture manufacturing, developed by Amelia Lee '23 in Advanced Product Design studio, taught by Jeremy Bilotti.

PHOTO: AMELIA LEE

DESIGN

A New Dawn for Design

MIT Morningside Academy for Design champions creative, cross-disciplinary thinking

Design is everywhere at MIT, incorporated into research and academics in fields as diverse as artificial intelligence, bioengineering, and music. The Institute is home to the nation's first department of architecture, established in 1865, which began offering a widely popular design minor in 2016. Now, the new MIT Morningside Academy for Design is harnessing these resources to take design to a new level, both on campus and beyond.

Launched in March 2022 as a major interdisciplinary center, the Academy builds on the Institute's leadership in design-focused education and aims to be a global hub for design research, thinking, and entrepreneurship. MIT professors **JOHN OCHSENDORF**, Morningside Academy founding director, the Class of 1942 Professor, and professor of architecture and civil and environmental engineering, and **MARIA YANG '91**, Morningside Academy associate director, the Gail E. Kendall Professor of mechanical engineering, and associate dean of the School of Engineering, discuss how the Academy will elevate design at MIT and in the greater world, supporting students and faculty who are champions of innovation.

> "Design is the primary mover that gets you from a basic technology to something that is usable by a human being," Yang says.

What does "design" mean, and why is it so important, especially here at MIT?

OCHSENDORF: Design is many things to many people. In some cultures, when people say "design" they refer to aesthetics, the external appearance of a product or structure. But the definition is much broader than that—design is how we deploy technology to serve people. That's particularly important to emphasize at MIT, where we're creating and embracing new and existing technologies every day.

YANG: We talk about making a "better world" at MIT, and design is a great way to approach that. Design is the primary mover that gets you from a basic technology to something that is usable by a human being. For example, we have all sorts of technologies that exist for clean cooking, but how do you translate that research into a clean-burning cookstove that will be embraced by families in low-income countries? Or consider a new vaccine. It might look great in the lab, but someone must figure out the system to get it in a syringe, refrigerate and deliver it, educate people, and make it available—the whole process. These examples take basic technology and use design to connect it to users, and that translation can be very hard.

John Ochsendorf and Maria Yang '91, leaders of the Morningside Academy for Design, outside the under-construction Metropolitan Warehouse building, which will be home to the new Academy and serve as a design hub for all of MIT.

PHOTO: TONY LUONG

An artistic rendering of a double-height design and review space on the second floor of the renovated Met Warehouse, which will showcase student design work.

IMAGE: COURTESY OF DILLER SCOFIDIO + RENFRO

OCHSENDORF: With a design-oriented perspective, the framing of the problem becomes as important as the solution. In an educational setting, when students and researchers are challenged with an open-ended design project, they must frame what is important, develop novel solutions, prototype them, and think about how they can scale them to work in the world. That is such a valuable experience and an amazing way of applying the brilliant technical ideas that our students are learning.

What are the goals of the Morningside Academy, and how will this new entity alter the design landscape at MIT?

OCHSENDORF: The Academy supports students and faculty who are conceiving and working on novel design solutions across disciplines. Design-based projects are a perfect way to cut across disciplines, because you're in search of a common solution. We're creating design leaders of the future who represent the broadest spectrum of humanity, both in their own experience and in the projects they pursue. Our priorities include developing curricula to support new design-related classes, funding undergraduate research projects that have a strong design component, creating high-profile graduate fellowships, and exposing students to research and educational opportunities in design at and beyond MIT. On a broader scale, we want to make sure that when people think of creativity and design, they think of MIT as the leading university in the world. STEM—science, technology, engineering, and math—should be synonymous with creativity, invention, and design, but right now it's not for many people, either in the public or in our professions.

YANG: Building a larger design community within MIT is particularly important. We want to make sure everyone knows that people do design here and to bring those people together. When I was a mechanical engineering major here, I would have loved to be a part of a larger design community, but it really wasn't something I was aware of on campus, and I've heard similar sentiments from other alumni. With the Morningside Academy, we're excited to raise the visibility of design on campus and share that with the outside world. We're creating new initiatives but also leveraging existing MIT programs and assets.

Why is interdisciplinary collaboration a key focus of the Academy?

OCHSENDORF: New insights emerge when you bring together expertise from different disciplines, and MIT has always embraced this idea to some degree. We envision the Academy bringing undergraduate engineering majors together with Sloan MBA students to craft new products, for example, or pairing Department of Urban Studies and Planning fellows with biochemists to work on challenges relating to public health. This will happen through courses and public programming but also through common spaces and social activities. One of our core ideas is to create cross-fertilization by offering graduate fellowships for anyone who's working in design in any discipline and by bringing that cohort of new fellows together so they can look for methodologies and approaches from other fields that apply to their own work. It's important to support risk-taking designers who are thinking outside the box, even if their ideas are radical for their discipline.

In general, do students arrive at MIT with design on their radar as something they want to pursue?

OCHSENDORF: One of the great joys of teaching at MIT is that our students are inherently designers—creative tinkerers who are already making and thinking. Many of them, no matter their field, arrive with a design portfolio. That trajectory should extend even further once they're here so that they're as comfortable tackling open-ended, ill-defined problems as they are in solving well-defined, closed-form equations.

YANG: That said, we have a lot of students who come in with strong technical skills but not much design experience. When they take a design class here, we often see a little switch go off as they realize they have the freedom to be creative in a different way. We want to support that passion and make them understand that it's something they can bring to their work at MIT and to their future careers.

How can physical spaces, like the Metropolitan Warehouse currently under renovation, support that interdisciplinary mindset?
YANG: Space for people to come together and incubate ideas, generate new thoughts, and build a sense of community is so important at MIT. The Academy is a driver for those facets of community-building, and the Met Warehouse will eventually be a fantastic physical manifestation of that for design, both by hosting programming and by acting as a social space.

OCHSENDORF: MIT's innovative spirit and ability to work across disciplines is also inherent in our campus architecture overall, with interconnected buildings that for the most part don't have boundaries between departments. This fluidity is a hallmark of our culture, and the opportunity and the challenge for the Met Warehouse as a hub for design is to be a continuation of that ecosystem.

Design can be an important factor in promoting equity across populations. How will the Academy make progress in this area?
YANG: "Design justice" is a movement that rethinks design processes to open up design to participation by a broader cross-section of the community to address inequality. In the Academy's efforts to champion design across disciplines, we have the opportunity to help our instructors and students take these principles into consideration when they design products and systems. There can be a big gap between having an awesome technology that works in the lab and something that is actually useful and equitable for end users from various populations. To make truly socially impactful change, we must design things in a way that deeply considers the human side of the equation.

OCHSENDORF: When designing, it's critical to understand the cultural context and to consider why end users would desire any particular technology. Many of the challenges that the planet faces, from climate change to public health to inequality, can be tackled if we use a design lens to consider solutions. We need solutions that are not purely technical and not purely policy-based. The goal of a designer is to imagine the world that we want to see.
—Joelle Carson

Q&A: Fueling Design at MIT


Lucas

The MIT Morningside Academy for Design is one result of a concerted effort to amplify design at MIT. **JULIE A. LUCAS**, the Institute's vice president for resource development, talks about how philanthropy and faculty commitment have built a strong foundation for design excellence that stretches well beyond campus.

How are MIT faculty from all departments involved with design at MIT?
Our brilliant faculty members are always finding creative ways to implement design principles in classrooms, labs, international learning opportunities, and makerspaces. In recent years, the Institute has made a concerted effort to elevate and strengthen interdisciplinary education, research, and innovation in design. In 2020, professors John Ochsendorf and Maria Yang '91 co-chaired a committee of 18 educators from across the Institute to envision ways to more fully offer design leadership in service to MIT and the world. When the committee released a whitepaper in 2021 with its recommendations, a design center like the Academy was aspirational. Now their insightful work, aided by visionary philanthropy, has made it a reality.

How has philanthropy accelerated design initiatives at MIT?
One way is through the founding of the Morningside Academy for Design. The Academy was established through a $100 million gift from The Morningside Foundation, the philanthropic arm of the T. H. Chan family. Thanks to this gift, several Morningside Academy fellowships were awarded to graduate students this past summer, and construction on the Metropolitan Warehouse was able to begin. The gift will also provide funding for faculty chairs. We are incredibly grateful to the Chan family for their generosity and for recognizing the importance of design at MIT, both for our students and the world. All gifts, no matter their size, are instrumental to supporting design at MIT.

Why is MIT the best place for the Morningside Academy?
We have the best landscape of technological research in the world, as well as a wonderful landscape of design. Ours is a culture of innovation, making, and collaborating, and the Morningside Academy puts those pieces together in an impactful way. The principles of the Academy, particularly its commitment to creativity, interdisciplinary approaches, and equitable design, are the embodiment of MIT values and resources. Most importantly, we have seen and continue to see how MIT students, faculty, and researchers are driven in their pursuit to design a better world. We must support them in those efforts, both through philanthropy and initiatives like the Morningside Academy.

Tech Upgrade for Housing

Larry Sass aims to "print" buildings

When many people think of 3-D printing, they envision toys, cards, or perhaps prototypes for new products. Larry Sass SM '94, PhD '00, associate professor in the Department of Architecture, thinks bigger: he wants to build houses using a system similar to 3-D printing.

It's not as audacious as it seems.

3-D printing has grown to become a mainstream term for home production with computers and machines. The machine that's central to Sass's work is actually a computer numerical control woodcutter—picture a 48-by-96-inch table saw—a rudimentary version of which was first designed at MIT in 1949.

Equipped with this technology, Sass has developed a forward-thinking vision for components of houses to be printed and shipped "just like a flat piece of furniture from IKEA." All that workers would have to do to build the house is assemble various numbered parts using clamps, glue guns, and rubber mallets. Since much less labor than usual is required, such houses should be faster and cheaper to build than traditional housing.

To accomplish this, Sass is exploring the idea of home production directly from 3-D models made using computer-aided design. The system decomposes an initial 3-D shape into smaller, interlocking parts ready for computer-aided fabrication and assembly as a physical kit of parts.

It's the same principle as the prefabricated home kits sold by Sears in the early 1900s. The difference is that those parts were cut by hand rather than rapidly printed or cut by computer.

Following family footsteps

As a descendant of enslaved people and the grandson of a builder in the Blue Ridge Mountains of Virginia, Sass says he is proud to be working in architecture. "Once upon a time, slaves built everything for everybody," he says. Noting that he grew up watching his grandfather build houses and furniture, he adds, "I think of him all the time when I work."

Sass's system can produce modern or traditional small buildings on demand, although so far technology is restricted to making smaller-scale exhibition structures. "I can make round buildings. I can make triangular buildings. I can reconstruct Queen Anne and Victorian homes, or I can construct a modern home," he says.

Yet, his work is about more than aesthetics. Such rapidly built homes could provide shelter in times of crisis. "This would be a great opportunity to make and deliver houses to people right after a disaster," he says. "I don't need power tools. I don't need experienced labor."

Sass's current research focuses on refining the sophisticated software necessary to make 3-D-printed homes truly viable. The software must possess a human-like understanding of how gravity works and how pieces fit together, which is a tall order. It's not yet ready for application; the field is still relatively new. However, change is coming.

"Woodcutting is on its way to becoming computerized. Imagine if you had a sketchbook and the pen or pencil came with a computerized device, helping you to draw a straight line," he explains. "In the future, a tape measure will be gone. A computer and a machine will do it all. The age of digital construction is on its way."

In his mind, it's long overdue: construction costs are so high that computer-aided design is going to become essential. "Homes could be manufactured in a matter of days as opposed to years by using software and machines to make buildings," he says. "We've ignored the construction industry with technology until the last two to five years."

In the future, Sass hopes to share his knowledge of digital carpentry with technical and trade schools. He's confident that construction workers will be able to make the transition easily. "It's very accessible technology," he says.

—Kara Baskin

"Homes could be manufactured in a matter of days as opposed to years by using software and machines to make buildings," Sass says.

PHOTO: M. SCOTT BRAUER

A Scroll Through Class Offerings

Students apply design principles to project work across the Institute

Above: Cloth simulation has applications in computer animation, garment design, and robot-assisted dressing. Students in Computational Design and Fabrication worked on a differentiable cloth simulator with additional gradient information that facilitates cloth-related applications. Their research was published by the Association for Computing Machinery.

IMAGE: YIFEI LI, TAO DU, KUI WU, JIE XU, AND WOJCIECH MATUSIK

Choosing classes from the MIT Bulletin each term is an activity rich with possibility for students. With 56 undergraduate majors, 58 minors, and 50 departments and programs offering graduate degrees, there is a dizzying array of choices. Inevitably, each student gets just a sampling of coursework—self-tailored to suit their tastes and ambition. But there are pedagogical themes that run across MIT, threading through an unlikely combination of classes. Design is one of these. In fields as diverse as aerospace systems, theater, and neurobiology, classes reveal approaches to design that are logical, practical, and rigorous. Here is a brief look at a few recent offerings.

6.4420 Computational Design and Fabrication
Introduces computational aspects of computer-aided design and manufacturing. Explores relevant methods in the context of additive manufacturing (e.g., 3-D printing). The course covers tools for every stage in the computational design pipeline, from hardware and its abstraction to high-level design specification methods.

SAMPLE PROJECT: A cloth simulator that uses a fast and novel method for deriving gradients.

"Computing plays a more and more important role in design because it allows you to figure out what the best designs are and to translate them into something that can be manufactured. This could work for anything. It can work for molecules, for webpage design, for drone design, for products, and so on."
—Professor Wojciech Matusik SM '01, PhD '03, Department of Electrical Engineering and Computer Science

"The class taught me useful concepts and fundamentals of the research areas and applications related to computational design and fabrication and prepared me to conduct relevant research. I highly recommend it."
—Yifei Li, graduate student, Department of Electrical Engineering and Computer Science

"Although computational design/fabrication is not my research area, I learned a lot during this class, and the final project led to a top-tier conference publication."
—Kai Jia, graduate student, Department of Electrical Engineering and Computer Science

10.321 Design Principles in Mammalian Systems and Synthetic Biology
Focuses on the layers of design, from molecular to large networks, in mammalian biology. Formally introduces concepts in the emerging fields of mammalian systems and synthetic biology, including engineering principles in neurobiology and stem cell biology.

SAMPLE PROJECT: Developing a computational model of dynamic synthetic gene circuits to identify how design choices at the DNA, RNA, or protein level impact performance.

"I hope students gain an appreciation for the diverse ways in which biology encodes functions. The layering of systems gives rise to rich and robust behaviors that enable complex processes to unfold with remarkable precision. Through the class, I hope they learn how we can integrate native design schemes into synthetic systems." —Assistant Professor Kate E. Galloway, W. M. Keck Career Development Professor in Biomedical Engineering, Department of Chemical Engineering

"In this class, I was able to design a model of the DNA damage response in mammalian cells that I continue to use in my PhD research. Overall, this class was great for learning how to model the regulatory mechanisms in biological systems and for designing new ways to engineer synthetic biological systems." —Adam Beitz, graduate student, Department of Chemical Engineering

"It was exciting to apply engineering strategies to biological systems and explore the unique principles governing these molecular and cellular contexts. The concepts related to design that I learned in this class are directly relevant to my graduate studies; I have already begun to use this knowledge and experience in my research." —Kasey Love, graduate student, Department of Biological Engineering

21M.731 Sound Design for Theater and Dance
Introduces the elements of a sound designer's work—such as music and sound effects that inform and make stage action plausible—to sound system design and placement and the use of microphones. Discusses how effective sound design enhances live performance by clarifying storytelling, heightening emotional experience, and making words and music legible to an audience.

SAMPLE PROJECT: An audio play adaptation of *Make Way for Ducklings*, Robert McCloskey's iconic children's book set in the Boston Public Garden.

"My hope is that students will come away from this class hearing the world differently. Sound design for theater is the art of storytelling, and also a technical craft, but it's only by really listening that we discover what stories we want to tell, and how to make them legible." —Christian Frederickson, technical instructor, Music and Theater Arts Section

"The class focuses on the different design elements of compiling sounds to reinforce an environment or to tell a story. We learned about quantifiable measures such as the different qualities of sound ranging from footsteps to music, and the number of sounds a person can distinguish before they blend into white noise. We also studied more artistic measures such as what sounds are comforting to an audience, and which set listeners on edge. It was a lot of fun learning to use the many different audio programs to edit and mold sound, and to consider listening to the world around me in ways I hadn't before." —Aquila Simmons '23, double major in mechanical engineering and theater arts

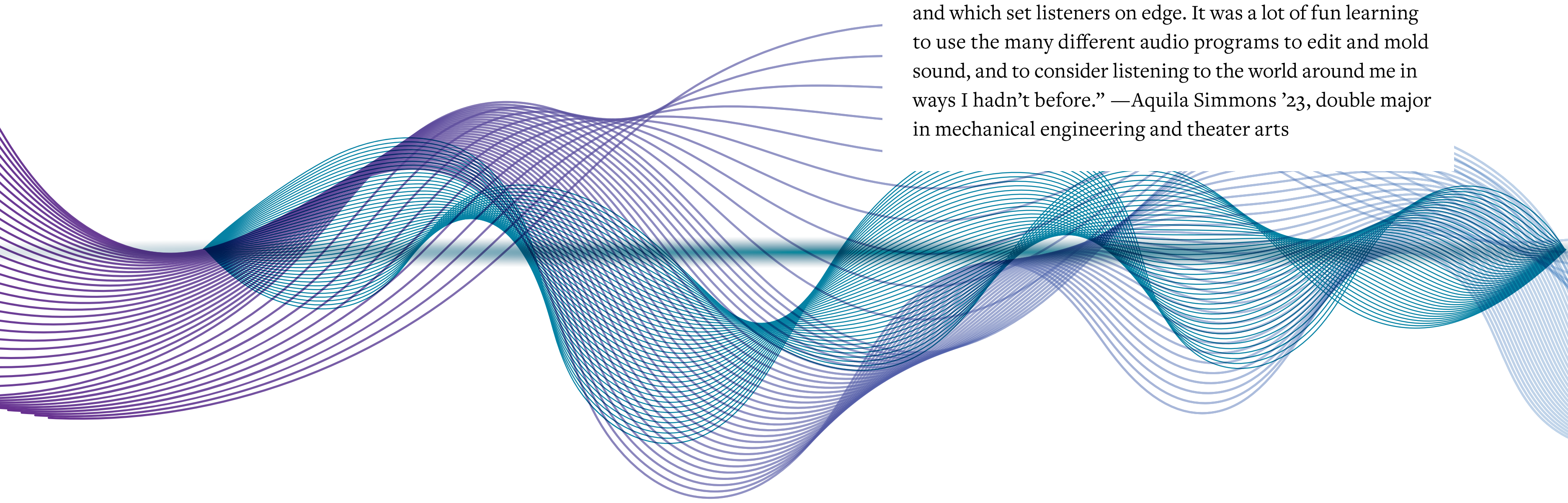


IMAGE: ISTOCK/OLENA AGAPOVA

Before the Unified Engineering class's annual flight competition, students make final adjustments to an airplane they designed and built. During the contest, participants attempt to have their planes achieve sustained flight in a circle while carrying the maximum payload possible.

PHOTO: DAVID DEGNER

Unified Engineering: 16.001 Materials and Structures, 16.002 Signals and Systems, 16.003 Fluid Dynamics, and 16.004 Thermodynamics and Propulsion
Presents fundamental principles and methods for aerospace engineering and engineering analysis and design concepts applied to aerospace systems. This class is taught within the context of the CDIO (conceive-design-implement-operate) framework. The goal is to educate the future leaders of the field on how to contribute to the development of new products in a modern, team-based environment.

SAMPLE PROJECT: Students, working in teams, conceive of, design, build, and fly an airplane in a competition.

"Aerospace systems problems are complex and highly multidisciplinary in nature. Unified Engineering connects the core disciplines by leveraging common intellectual threads and equips the students with fundamental skills to characterize the underlying mechanisms, create conceptual models, and design new solutions to address the technical challenges of the future." —Professor Zoltán Spakovszky SM '99, PhD '01, T. Wilson Professor in Aeronautics, Department of Aeronautics and Astronautics

"Unified Engineering provides a unique opportunity to get immersed in very modern, computational-based design practices as well as traditional design techniques built upon decades of physics and engineering fundamentals. For me, design is most fun when it is centered around a complicated problem, with many possible approaches to solving that problem. Combining computational tools with hand calculations and theory only adds to the fun!" —Benjamin Rich '24

2.75 Medical Device Design
Provides an intense project-based learning experience around the design of medical devices with foci ranging from mechanical to electromechanical and electronics. Projects are motivated by real-world clinical challenges provided by sponsors and clinicians who also help mentor design teams.

SAMPLE PROJECTS: A device to close an intracardiac defect, a cooling suit for astronauts, and an imaging device that aids in the detection of cervical cancer.

"This class is a team project-based class where students team up with local physicians and industry sponsors to solve real clinical needs. They come up with a working prototype in 14 weeks and learn design fundamentals and the logistics of translating medical devices to the clinic, including regulatory, intellectual property, and commercialization aspects." —Associate Professor Ellen Roche, Latham Family Career Development Professor, Department of Mechanical Engineering and MIT's Institute for Medical Engineering and Science

"This course introduced me to the world of medical devices, taught me key principles of design and engineering, and helped me apply these lessons to solving real-world challenges in health care." —Anup Sreekumar, graduate student, System Design and Management Master's program

16.83 Space Systems Engineering
Design of a complete space system, including systems analysis, trajectory analysis, entry dynamics, propulsion and power systems, structural design, avionics, thermal and environmental control, human factors, support systems, and weight and cost estimates.

SAMPLE PROJECT: Students participate in teams, each of which is responsible for an integrated vehicle design. This provides experience in project organization and interaction between disciplines.

"The students bring their expertise in aeronautics and astronautics from their undergraduate curriculum to the project and learn how to use their knowledge as well as identify other skills that are necessary to create a successful mission design through systems engineering." —Associate Professor Kerri Cahoy, Department of Aeronautics and Astronautics

"The students in this class have spent years at MIT learning and honing skills in aerospace engineering. This class finally gives them the opportunity to put them all together for a mission the class cares about. They learn the difficulties of integration of multiple subsystems and come out as well-rounded engineers." —Mary Dahl '20, SM '22, teaching assistant for the class

—Kathryn M. O'Neill

Taking Surveys Seriously

Political scientist crafts measured approach to capturing public opinion

In an era when "alternative facts" and "fake news" are political catchphrases, surveys are a crucial snapshot of public opinion. Like voting, surveys provide a megaphone to the electorate.

"In democracies, where the citizens have a voice in the direction of politics, we obviously want to know: What does the public think?" says Adam Berinsky, the Mitsui Professor of Political Science. A specialist in measuring public opinion, Berinsky designs surveys that strive for impartiality and accuracy.

He says well-designed surveys accurately capture public opinions, and they explain how firmly the public holds them.

"In survey design, there are two questions we need to ask. The first is, 'Whom do we interview?' The second is, 'What questions do we ask?'" he explains.

The "who" question has grown complicated. A generation ago, surveys were conducted via old-fashioned telephone, with pollsters cold-calling people. He dubs the 1980s the "golden age" of polling, when almost everyone had a landline—and actually answered it. These days, less than 10% of people agree to be interviewed, he says, thanks to caller ID on cell phones and other changing technologies.

For that reason, Berinsky's surveys are typically conducted online. A good survey, he says, is "concise, clear, intelligible." He aims for efficiency, taking no more time than a typical old-school phone call.

"Going into the survey, I know about how many questions I can ask people in 10 to 15 minutes, which still gives me time to ask them 30 to 40 questions," he says.

Of course, if you wanted to get a 100% accurate measure of public opinion, you'd have to survey the entire population. That is impractical in a nation of 330 million people, so good surveys use random sampling for best results.

"Think of it as a doctor taking a blood test. They can't drain your whole blood supply, so they take a sample. If your cholesterol is too high in that sample, chances are it is throughout your bloodstream. That's the beauty of the survey: we can learn about the whole American public without having to talk to everyone," he explains.

To ensure an appropriately broad swath of the population is surveyed, pollsters used a practice called multistage sampling, which divides a population into clusters. In this system, a canvasser might select 10 states, then choose 10 towns within those states, and, finally, identify 10 neighborhoods within those towns for polling. Such samples are the gold standard for polling.

In addition, Berinsky says, simple random samples have two important properties: each individual is chosen for inclusion in the sample by chance, and each member of the population has an equal chance of being included in the sample.

For national surveys, Berinsky typically aims to survey 1,000 respondents. "That sample size is adequate to describe national public opinion with reasonable certainty," he says. Since this swath is so broad, though, he always aims for understandable questions, with clear response options asked in logical order.

Where should voters go for reliable survey data? Berinsky says that while many news organizations are accused of bias, their surveys are generally reliable and agenda-free. "These are people who really want to get the polls right, so they win when they get the outcome correct and then get the story right," he says.

As for the next election cycle? The jury is still out.

"In the last 20 years, it has become harder and harder to conduct polls in advance of elections. In the last couple election cycles, for example, for whatever reason, Democrats were more willing to talk to pollsters than Republicans. Our polls, therefore, have tended to overestimate support for Democratic candidates," he says. "This is something we need to keep in mind when we think about polls going forward. Good polls measure public opinion writ large. That is always the goal."

—Kara Baskin

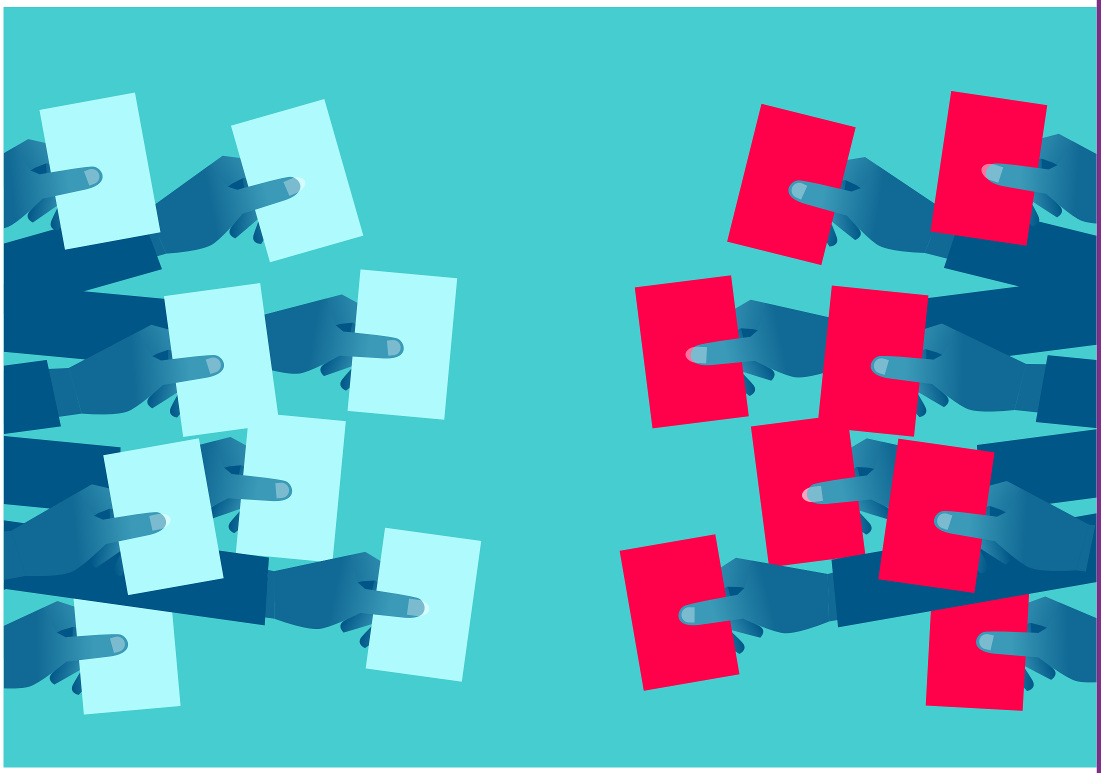
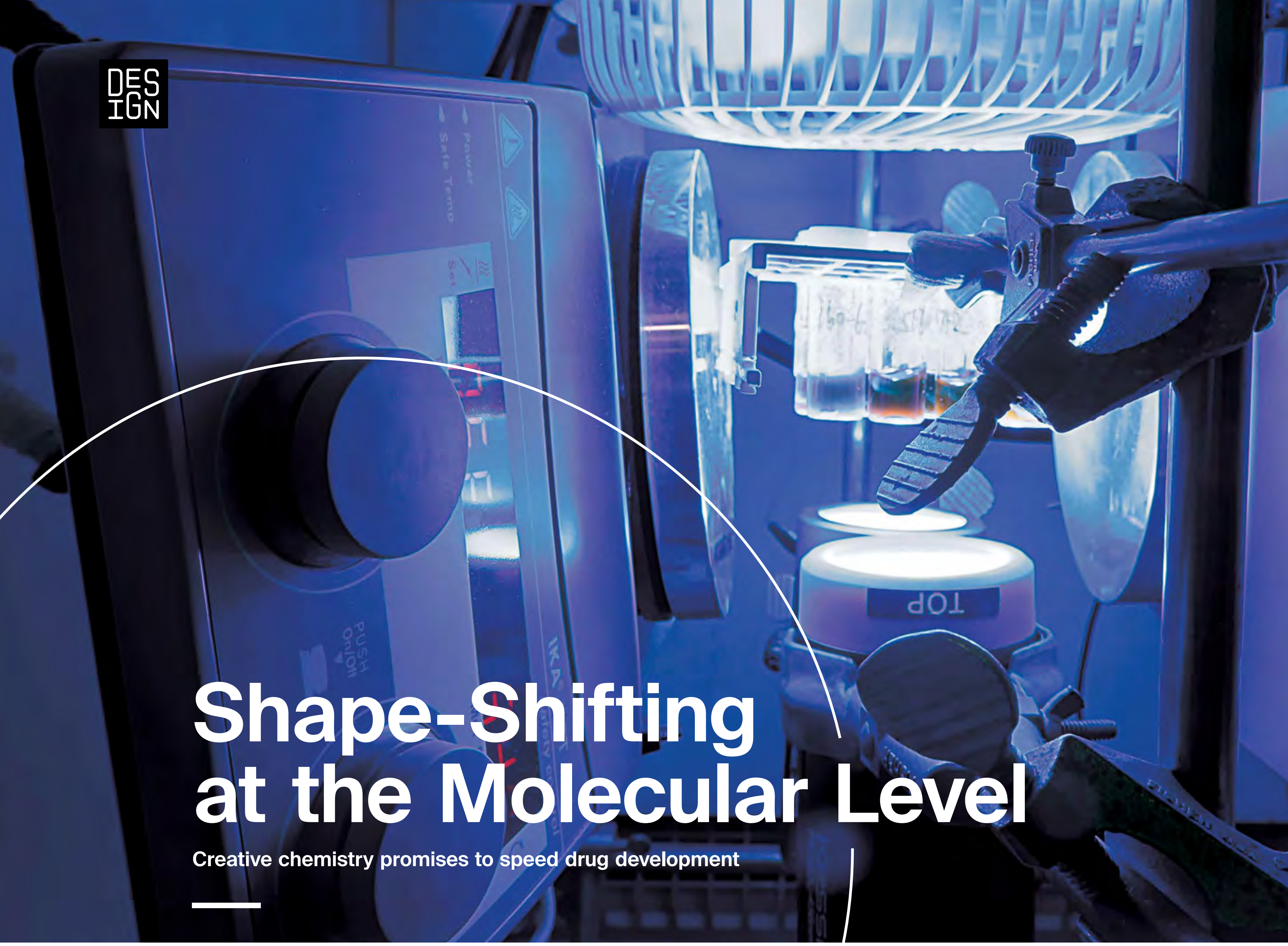


ILLUSTRATION: GETTY IMAGES

DESIGN



Shape-Shifting at the Molecular Level

Creative chemistry promises to speed drug development

Wendlandt

Organic chemist Alison Wendlandt designs molecules from the atoms up, with the goal of synthesizing useful substances faster and more efficiently.

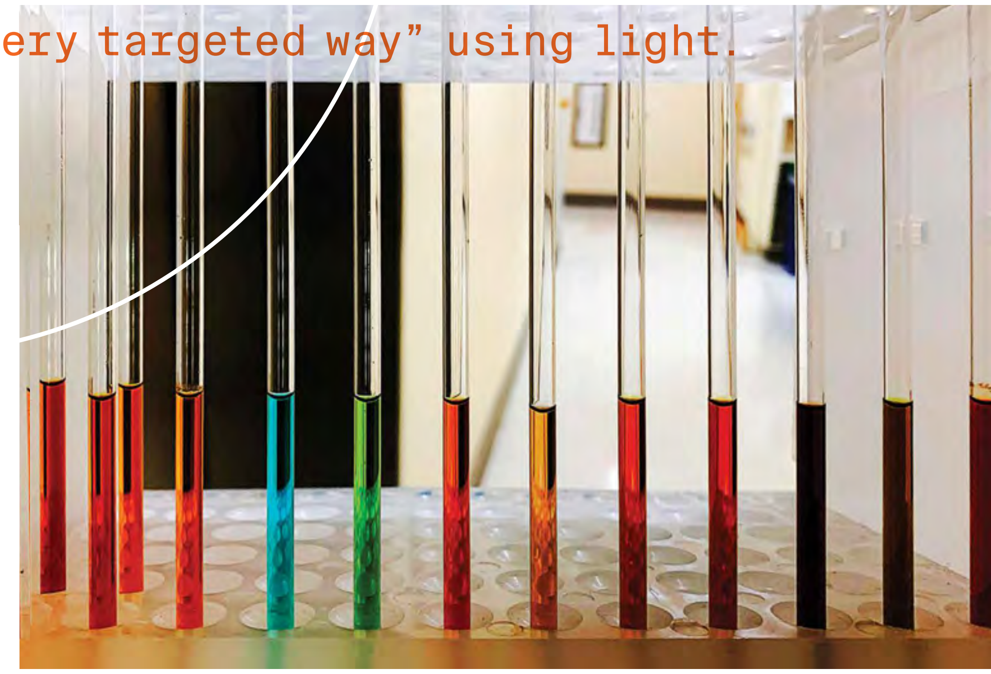
Her lab focuses on stereochemistry, or how molecules' atoms are arranged in space—a key criterion for pharmaceuticals because a drug molecule's shape determines how it interacts with proteins and other large molecules in and on our cells. For instance, the antihistamine levocetirizine makes you less sleepy than cetirizine even though the two molecules are isomers, which means they have the same number and types of atoms. The difference is in their shape.

Wendlandt, the Cecil and Ida Green Career Development Assistant Professor of Chemistry, says determining which bonds link which atoms in a molecule can be crucial to designing drugs such as those that interact with the body's enzymes. "We think about the connectivity of the molecule and how that might help fit the right drug into the right enzyme," she says.

In the 1800s, Louis Pasteur noticed that tiny facets on the edge of a crystalline organic acid were sometimes oriented to the right and sometimes to the left, and chemist Emil Fischer found that differences in the configuration of hydrogen, oxygen, and carbon atoms accounted for differences in sweetness between, say, glucose and galactose. Like many organic chemists, Wendlandt has learned to rotate complex schematics of molecules in her head. "It's not unlike other aspects of design, like architecture," she says.

More than a century after Pasteur's and Fischer's revelations, fine-tuning the spatial arrangement of atoms within molecules is still one of organic chemistry's biggest challenges.

"Typically, if you wanted to add energy to a reaction, you'd turn the heat up, which means every molecule, every bond is experiencing the same influx of energy," Wendlandt says. "We selectively apply energy in a very targeted way" using light.



Alison Wendlandt's research team relies on light produced through blue LEDs made for fish tanks (left). Within a fume hood covered in orange film to counteract the blue light, chemists irradiate small vials of substances (right) in the presence of a photosensitive catalyst.

PHOTOS: COURTESY OF THE WENDLANDT LAB

To make designing new, potentially useful substances even more challenging, certain isomers are mirror images of one another; awareness of this "handedness," or chirality, is particularly important in drug development. A chiral isomer may produce the desired therapeutic effect while its achiral version might be ineffective or even dangerous—take the infamous example of thalidomide, prescribed in the 1950s for morning sickness. The left-handed molecule was safe and effective while its right-handed version was highly toxic, causing a generation of birth defects.

Rearranging molecular pieces

Typically, assembling a new molecule is a little like assembling a jigsaw puzzle: the way the pieces go together is fixed. Wendlandt identifies strategies to render those static positions dynamic.

"We use straightforward and unselective chemistry to assemble the molecule with the desired bond connectivity, and then use our methods to tune the stereochemistry of any chiral centers," she says. "This contrasts with the typical way in which complex chiral molecules have been made, where the correct stereochemistry must be set when the bond connections are forged."

Creating the bonds first and then tuning the stereochemistry can make the process of developing new molecules quicker and easier, she says. Essentially, instead of creating a new puzzle from scratch, her team rearranges individual pieces.

To do this, Wendlandt's team performs highly selective catalytic reactions that access specific atoms. Breaking and reforming chemical bonds requires energy. "Typically, if you wanted to add energy to a reaction, you'd turn the heat up, which means every molecule, every bond is experiencing the same influx of energy," she says. "We selectively apply energy in a very targeted way" using light.

Her research team relies on light produced through an unlikely source: blue LEDs made for fish tanks. Within a fume hood covered in orange film to counteract the blue light, chemists in Wendlandt's lab irradiate small vials of substances in the presence of a photosensitive catalyst. "Selectively adding photons allows us to drive the reaction to a thermodynamically unstable place," allowing the researchers to selectively break and reform atomic bonds.

"If you can take a molecule and interconvert between its many isomers selectively, you don't have to go back to the beginning and make a completely new molecule. So, it's more about shape-shifting at the late stage," she says.

Wendlandt has successfully used this light-catalyst approach to synthesize rare sugars used in a host of antiviral, antibacterial, anticancer, and cardiac drugs. The ability to synthesize rare sugars, limited in nature, could help meet increased global demand.

Wendlandt, originally from Colorado, hadn't envisioned a career centered on manipulating molecules, but she became enamored with organic chemistry at the University of Chicago.

A cellist, she likens organic chemistry to jazz. "Once you understand the basic rules of jazz, you can really have a lot of fun," she says. "You can riff in the space. "That's the essence of what any scientist does—play within some interesting space."

—Deborah Halber

Faith Jones '22 presents her Re-Woven chair, whose sling is designed to be infinitely un-woven and re-woven, to product designers from Emeco and Formlabs as part of 4.041 Advanced Product Design.

PHOTO: LAVENDER TESSMER

From Major to Minor, Design Proves Key

Students see benefits of adding creative skillset to their repertoire

Since its introduction six years ago, the MIT Department of Architecture's design minor has consistently ranked among the most popular minors on campus. The department's design major, launched two years later, has been similarly appealing, enticing students studying such disciplines as computer science, mechanical engineering, and biology to also earn a bachelor of science in art and design.

"Almost all our students are familiar with the scientific method, which they learn at an early age," says Paul Pettigrew MArch '88, who returned to the architecture department in 2016 as manager of special projects. "They take a sequence of science classes where they apply the scientific method repeatedly in different contexts. We take the same approach in teaching design. We teach a design process: ideate, iterate, prototype. If a student learns that process, they can apply those principles to any number of disciplines."

For many undergraduates, design studies offer a novel approach to creativity, one that complements their studies in other departments. "Design as a field of study is very young," says Janice Tjan '22, a mechanical engineering student who added a double major in design her second year. "But as a process it's very old. A lot of mechanical engineering students are now taking design classes or minoring in design just to get that perspective."

For Daniela Carrasco '18, who majored in computer science, design at MIT first served as an outlet to make art and build tangible objects. "I wanted to use tools other than the tools you find on a computer," says Carrasco, who today designs software at Adobe. "But what I really learned was how to be creative. Before my design studies, I thought creativity was something nebulous, something you are either born with or not. At MIT, I learned that creativity is a skill, just like math, that you can practice, learn, and perfect."

A very techy program

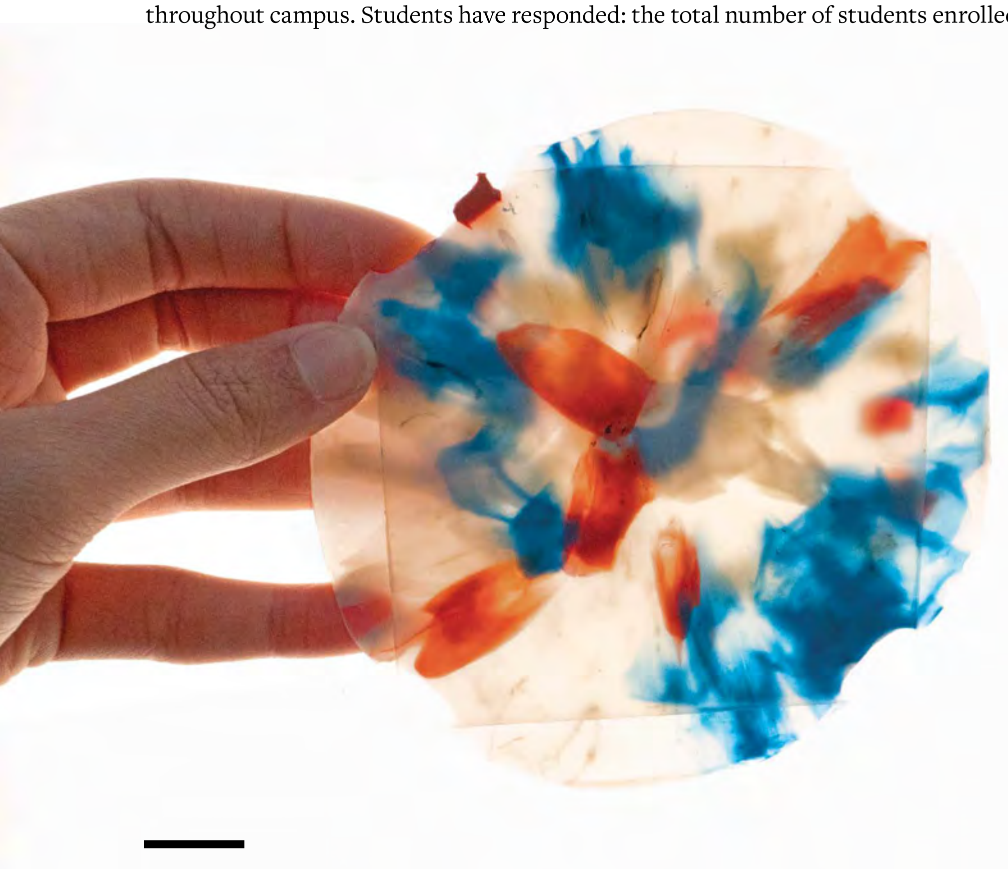
Design at MIT is taught differently than at most universities. Few art or design schools expect a similar level of technical, material, or computational expertise in their students. And very few university design programs are as rigorous or demanding. "Of all the majors, design majors turn in their theses later than anyone else," says Tjan, who for her senior thesis worked to improve hearing aids. "The design process requires so much time. There are so many questions to answer, and often it can feel like you'll never be completely satisfied with those answers. Design is really blood, sweat, and tears."

> "Design is really blood, sweat, and tears," Tjan says.

"This isn't just about aesthetics," says Skylar Tibbits SM '10, associate professor of design research who directs the design minor and major programs and is one of the creators of the undergraduate design program. "It's about learning to think and create in a whole new way. These are the best and brightest of MIT undergraduates, who study computer science, engineering, physics, or chemistry on one side of the campus but are also super talented in arts and design. Left brain and right brain. Mind and hand. This is the pure ethos of MIT."

For Jierui Fang '20, who majored in design with minors in computer science and biomedical engineering, the real value of design education at MIT is versatility. "In the professional world, rules and roles are often in flux," says Fang, who worked on biomedical device software after MIT and recently completed her first year in a master's program in design at Stanford. "Technical ability and concrete skills are important. But the ability to adapt, to speak other people's languages, and to gain perspective in an unfamiliar environment is even more important. That is what I learned studying design at MIT."

MIT's minor and major in design and its expanded offering of undergraduate design courses have made design available both in the Department of Architecture and throughout campus. Students have responded: the total number of students enrolled in design courses at MIT has increased nearly three-fold since 2016. Currently, there are close to 70 students majoring or minoring in design at the Institute. More than 200 undergraduates enroll in design subjects each semester.



Sample of an experimental material that recycled furniture could be made from in the future, developed by Amelia Lee '23 in MIT's Advanced Product Design studio.

PHOTO: AMELIA LEE

The MIT design program has established a collaboration with the École cantonale d'art de Lausanne in Switzerland. MIT's program also has numerous partners in fields including furniture, software, luggage, and lighting who help connect the research and instruction at the Institute to industry. For example, Jaye Buchbinder, head of product development and sustainability at furniture maker Emeco, was an industry collaborator in 4.041 Design Studio: Advanced Product Design taught by Jeremy Bilotti, a course where students learn to identify client needs and design manufactured products such as furniture.

"At the end of the class, the student projects weren't just pieces of furniture," Buchbinder says. "They were new ways of thinking about what design is and how we manufacture. The curiosity the students—and teachers—showed in that room made us excited for the future."

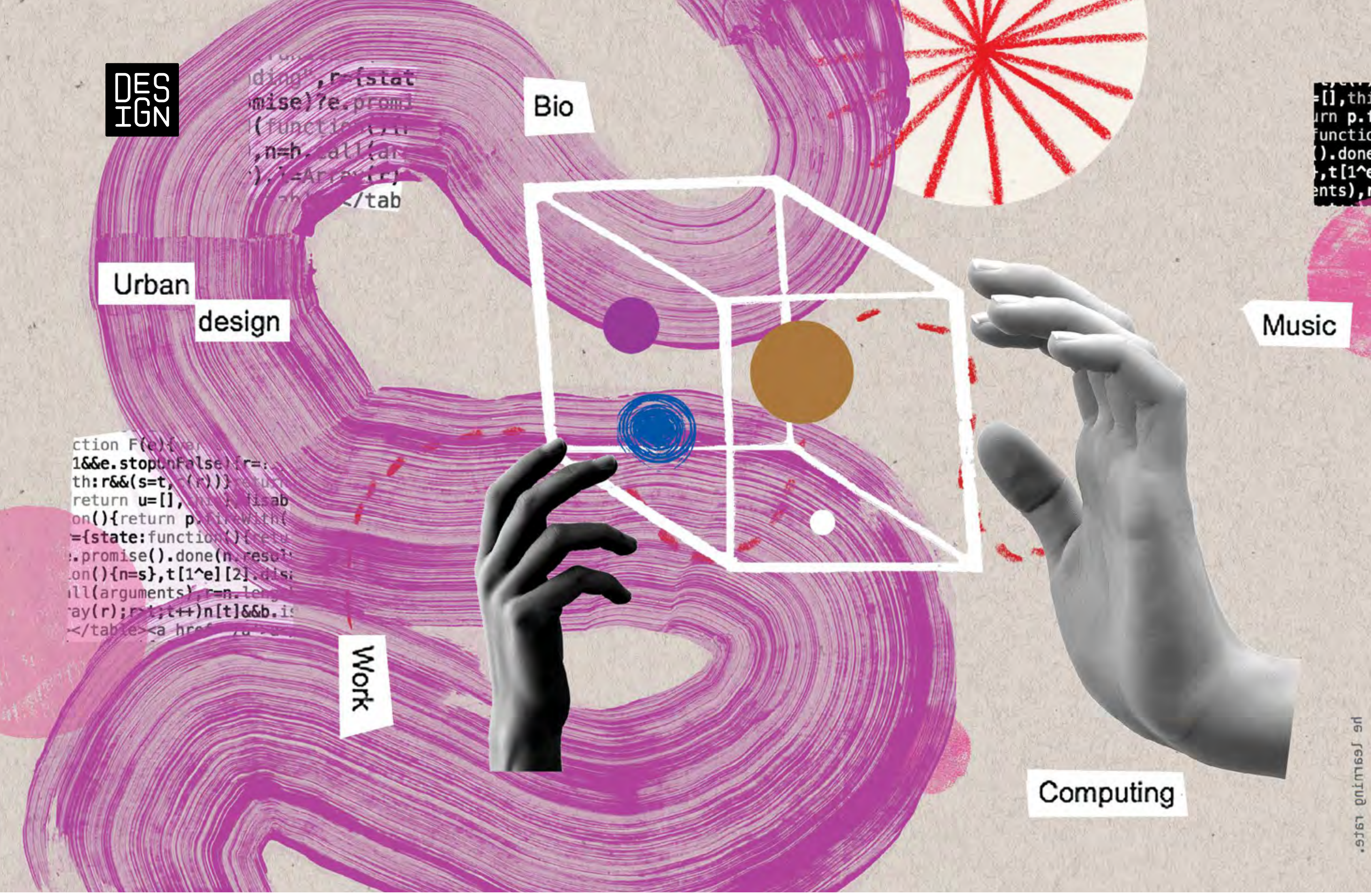
Design students at work

The design minor and major build on the 150-year-old Department of Architecture's history of pioneering design research and scholarship, offering students even more ways to engage with the discipline. "I can show prospective students a list of graduates with a major or minor in design, all of whom are working at interesting jobs or attending graduate school," says Pettigrew, who also teaches 4.021 How to Design Anything, a course that introduces students to fundamental design principles and processes. "Students and particularly parents find this reassuring."

Leslie Yan '22, who majored in mechanical engineering and design, says working in both disciplines at the same time has made her a better engineer and a better designer. "The storytelling and presentation techniques I learned in design classes inform my engineering choices," says Yan, who is going to work for Microsoft on its Surface line of consumer devices. "And my engineering training helps me make more timely and efficient design decisions."

Carrasco, who says she would have majored in design had the major been available when she was at MIT, believes her training in design helped her land her job at Adobe. She believes her dual expertise in engineering and design bring added value to her team. "It's not all that common to find a software engineer who also has design experience," she says. "Having insight into the other side—the design side—helps you bridge the gap between those sides. Everyone benefits."

—Ken Shulman



ILLUSTRATIONS: ANDREA D'AQUINO

Design for Anything and Everything

Across MIT, researchers apply disciplined approach to form and function

"The essence of design ... lies in the process of discovering a problem shared by many people and trying to solve it."
—Kenya Hara, author of *Designing Design*

Thoughtful, intentional planning is central to design for any purpose, so it's not surprising that designers can be found everywhere at MIT. Researchers work on everything from building better robots to reimagining urban landscapes. Here's a glimpse at just some of the design work underway.

With vast applications in machine design, a mechanical linkage mechanism—such as the complex version shown at right—translates one type of motion into another. Working in assistant professor Faez Ahmed's DeCoDE lab and in collaboration with the MIT-IBM Watson AI Lab, doctoral student Amin Heyrani Nobari SM '22 created LINKS, a dataset of a hundred million planar linkage mechanisms aimed at enabling high-performing data-driven models and helping engineers optimize their designs.

IMAGE: AMIN HEYRANI NOBARI

Elevating the health of our cities

"The resilience of our cities and human landscapes is the biggest design challenge of the 21st century," says Nicholas de Monchaux, professor and head of architecture at MIT.

That's why de Monchaux is creating a suite of digital tools to help cities weather the challenges presented by climate change, in part by optimizing overlooked urban spaces such as alleys and vacant lots. If such remnant parcels were landscaped, they could aid in drainage and mitigate air pollution, he explains.

"Cities are organic living things, just like a plant or a human body," he says. "You need to elevate the health of what's there."

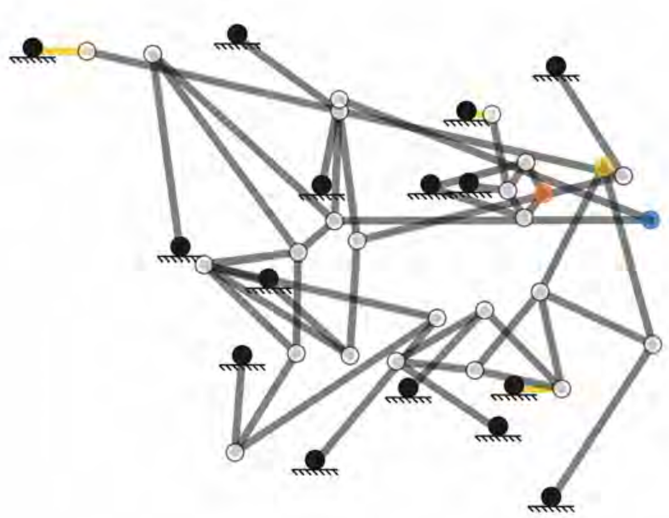
In an ongoing project begun at the University of California at Berkeley, de Monchaux has digitally mapped thousands of abandoned or underused urban sites and created site-specific designs for park-like community spaces that can mitigate ecological threats from storm flooding, heat waves, and air pollution. Specific design proposals for 3,659 individual sites were published in de Monchaux's book *Local Code* (Princeton Architectural Press, 2016).

The aim of this work is to link urban health with social welfare in a "distributed immune system for the 21st century city," says de Monchaux.

Collaborating with Carlos Sandoval Olascoaga SM '16, PhD '21, a former Berkeley colleague who is now a postdoctoral associate and lecturer in MIT's School of Architecture and Planning, de Monchaux is employing the same digital mapping techniques to identify New York City properties that might be used as urban farms.

In this work, both researchers say they hope to promote the democratization of design by enabling community members to collaborate in selecting farm sites. Their mapping software allows non-technical users to evaluate the overall social and ecological impact of a site by graphically synthesizing data analytics and providing interactive feedback.

Sandoval Olascoaga says he hopes the work leads to cities that are shaped "collectively and holistically, rather than from the top down." —Mark Sullivan



"The vision of the lab is to create a world where humans and AI design together," Ahmed says.

Democratizing product creation with AI

Thomas Edison once said: "I find out what the world needs. Then I go ahead and try to invent it."

Faez Ahmed seeks to harness the power of artificial intelligence (AI) to help people connect with their inner Edisons.

Ahmed and his team at the Department of Mechanical Engineering's Design Computation and Digital Engineering (DeCoDE) Lab are creating new AI-driven methods to generate novel designs for various products, from bicycles to aircraft and ships. Using a database of designs created by people as a starting point, the team applies new machine-learning algorithms to identify promising elements and then uses computer simulations for accelerated discovery.

"The vision of the lab is to create a world where humans and AI design together to solve some of our biggest challenges," says Ahmed, the Brit and Alex d'Arbeloff Career Development Professor in Engineering Design and assistant professor of mechanical engineering.

When humans design new ships or bicycles, he says, the tweaks they make tend to be incremental. "They take a design and maybe change it a little bit. They may not think out of the box," Ahmed says. Also, it is difficult for people to consider millions of options.

This is where Ahmed's method comes in. "We create new algorithms that can learn from humans and then work with humans to create better product designs," he says.

Humans guide AI to tailor and perfect their designs, he explains. "Right now, designs are created at the headquarters of major industrial companies," he says. With AI-enabled design democratization, "even if you're not trained in engineering methods, you can create designs."

For example, working with a dataset of thousands of bicycle designs made by bicycle enthusiasts, the group devised machine-learning tools to distinguish between styles, functions, and parts. The tools leverage this knowledge to generate innovative new bike designs that meet customer needs. Ahmed's team is now working to build algorithms that can create designs worthy of being patented. —Mark Sullivan

Exploring sonic possibilities

Engineering is a creative process, says Ian Hattwick, who helps MIT students tap this creativity to make music in his class 21M.370 Digital Instrument Design. Technology is central to the artistic practice of the class, in which students examine aspects of sound and learn to build instruments through the design of software systems, hardware interfaces, or interactive artworks.

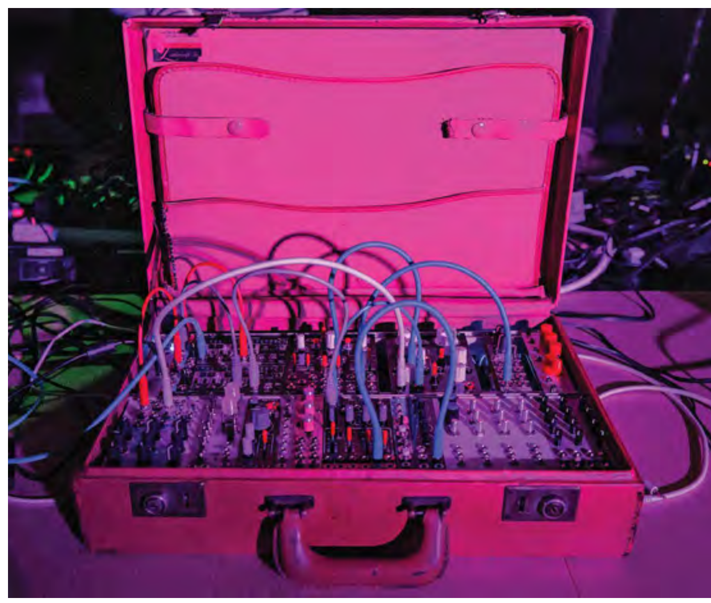
"There are very tangible qualities to sound," says Hattwick, an engineer, professional musician, and a lecturer in Music and Theater Arts. "It's fun to explore but unpredictable. Students get a handle on that unpredictability and interact with emerging sonic processes and sonic results." Successful instrument building, he points out, requires interdisciplinary skills, including multimedia software programming and electronic and mechanical engineering.

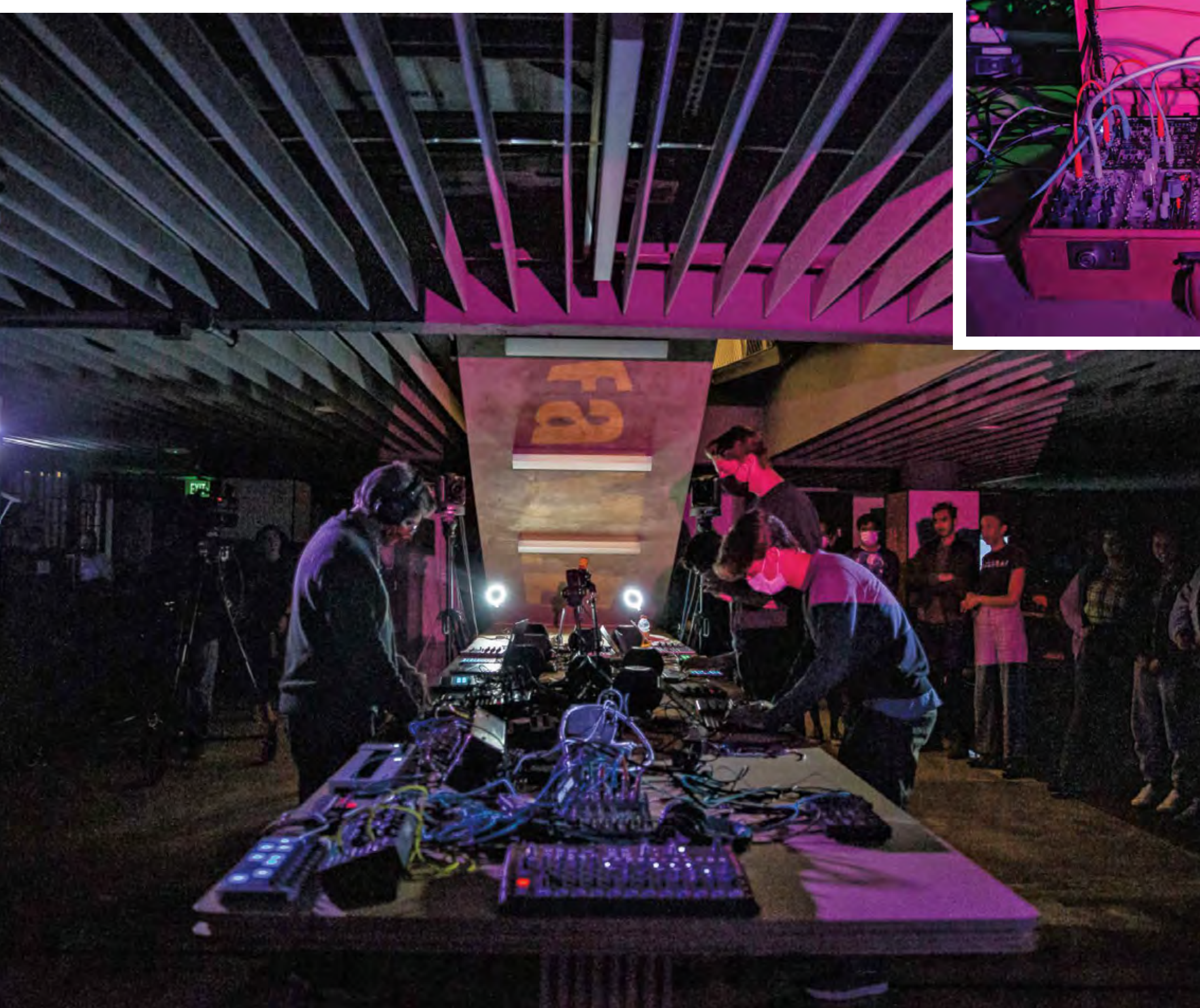
During the 2020–2021 school year, Hattwick invited professional musicians who incorporate digital and electronic musical instruments into their practice to participate in an online concert, "Engineered Expressions." Students enjoyed performances by Myriam Bleau, Marije Baalman, 80KV, and Author & Punisher, then had the opportunity to engage with the artists in a virtual workshop.

Digital Instrument Design students study the work of such contemporary musicians, then design, build, and play instruments consisting of electronic, mechanical, and software components. Many work on their designs in the Voxel Lab, the music and art makerspace in the Institute's new InnovationHQ in Kendall Square. The lab is also headquarters for FaMLE, the MIT Laptop Ensemble, which under Hattwick's direction explores emerging digital music practices such as live coding, a practice in which performers write code in real time to generate music and visuals.

Hattwick enjoys watching students gain artistic and technical confidence as the Digital Instrument Design course progresses. "They should feel empowered to make decisions, think through the implications of the decisions they're making, and follow their interests in the things they create."

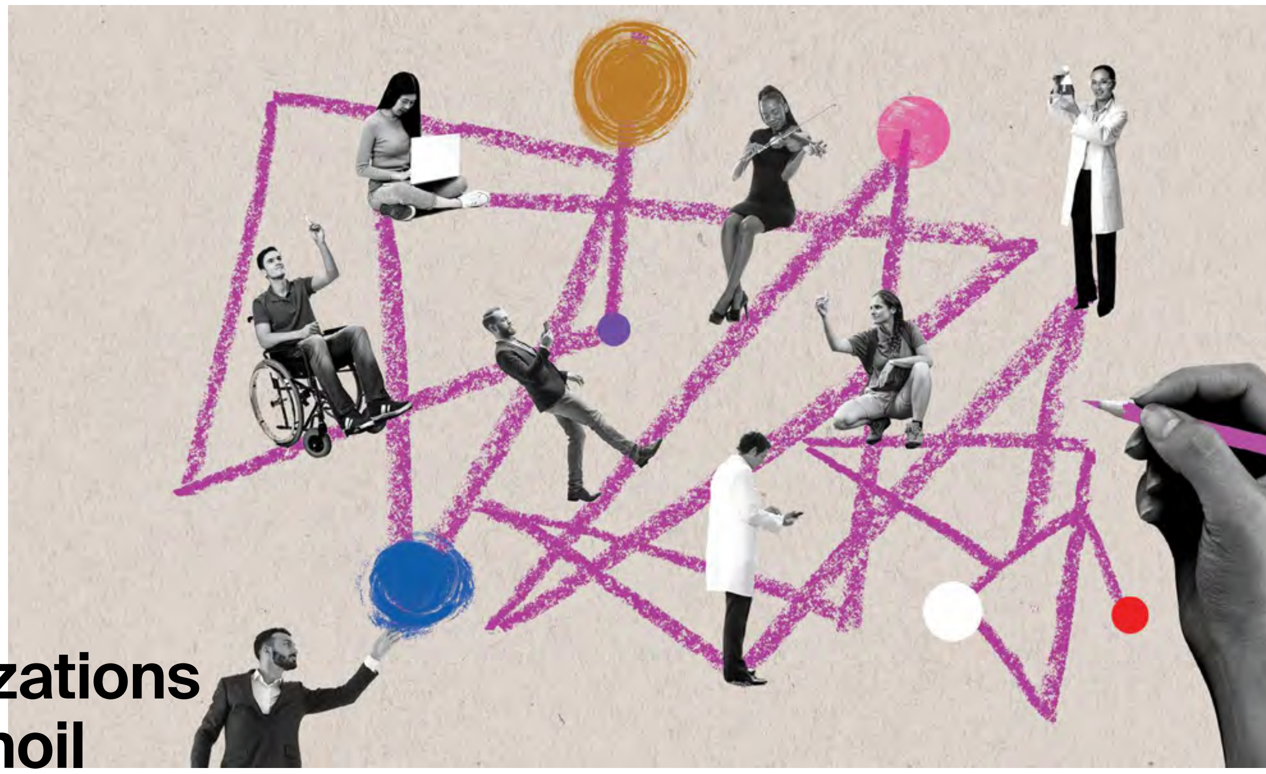
—Christine Thielman





Students in FaMLE, the MIT Laptop Ensemble, experience a variety of hands-on techniques, including live coding, for composing and performing electronic music.

PHOTOS: DANNY GOLDFIELD



Helping organizations learn from turmoil

Work changed drastically during the Covid-19 pandemic. While the sudden switch to remote operations was incredibly overwhelming, for many workers it was also a time of intense productivity: many nonessential tasks fell away as organizations concentrated on their most mission-critical work.

Nelson Repenning PhD ’96, associate dean of leadership and special projects at the MIT Sloan School of Management, says this is a known phenomenon. “Organizations tend to become much more functional during a crisis,” he says.

Unfortunately, Repenning says, leaders rarely adopt such a focused approach to addressing everyday work challenges. That’s why Repenning created a new approach called dynamic work design. Developed with Donald Kieffer, senior lecturer in operations management at MIT Sloan and former vice president of operational excellence at Harley-Davidson, the approach is intended to channel the energy and purpose one might experience in a crisis—without the actual crisis.

There are four main principles to dynamic work design:

- Establish smart, actionable goals based on what problems exist.
- Identify a process to escalate problems effectively and solve them regularly and in a timely fashion.
- Take advantage of workers’ creativity and talent to better address the identified problems, interactively, as work continues.
- Identify the “ideal” number of challenges you should be working to solve in an organization. This step essentially creates a list of mini crises—bubbling up problems that can then be solved individually, in bite-size pieces.

One early adopter of dynamic work design is the Broad Institute of MIT and Harvard, and it has seen drastic improvements in productivity, Repenning says. The research center is now able to set budget and planning targets every quarter rather than annually. “For Covid-19 testing, they went from never having done a PCR test to being one of the top-10 labs in the country in about six months. Not many organizations could pull that off so quickly,” he says. —Katherine J. Igoe

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READ MORE AT

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Dynamic work design is intended to channel the energy and purpose one might experience in a crisis—without the actual crisis.

(↗)
TAKING A HARD LOOK AT SOFTWARE DESIGN

“For software, the design process should be based on identifying concepts—using old concepts that work well and inventing new ones when necessary,” says Daniel Jackson SM ’88, PhD ’92, professor of computer science.

READ ABOUT HIS WORK AT

spectrum.mit.edu/jackson

DES
IGN

Creating robots with human-level perception

"This is a great time for robotics," says Luca Carlone, the Leonardo Career Development Professor in Engineering and associate professor of aeronautics and astronautics. "What we do can have a real impact on the world."

Carlone and his team at the SPARK (Sensing, Perception, Autonomy, and Robot Kinetics) Lab are working to help robots navigate the world with ease, the way humans do. "As humans, we form a complex internal model of the external world, which we use to navigate and make decisions," says Carlone. "Similarly, robots need spatial perception algorithms to understand their surroundings."

A lack of scene understanding by an autonomous vehicle can lead to failures—for example, a self-driving car may crash as a result of incorrectly interpreting its sensor data. SPARK Lab researchers are developing robust and certifiable algorithms and systems that enable robots to understand 3-D scenes. They have also developed groundbreaking tools to build hierarchical models (called 3-D scene graphs) of the environment as the robot navigates in it. "My lab is about pushing the state-of-the-art in perception, increasing the robustness of the algorithms, and getting performance guarantees," says Carlone.

SPARK Lab is also working on the flight and grasping capabilities of robots and drones, since many aerial manipulators are still relatively clumsy. Carlone's goal is to take lessons from nature: imitating the way an eagle, for example, uses its muscles and tendons effectively to grasp and hold prey. To help a drone move more like an animal, Carlone's team retrofitted it with soft silicone fingers that can pick up and hold objects—a vital skill for machines used in disaster response missions. In a recent study, he says, "We were able to achieve a 92% grasping success rate, showing that the soft gripper enables grasping where a rigid gripper would fail." —Christine Thielman

(↗)

INSPIRED TO HEAL THE HUMAN HEART

"Whether you're designing a medical device or a building or a structure, a lot of the same principles apply," says Ellen Roche, associate professor at the Institute for Medical Engineering and Science and in the Department of Mechanical Engineering.

READ ABOUT HER WORK AT
spectrum.mit.edu/roche

Tweaking proteins to thwart disease

Proteins do just about everything inside a cell. They build its structure, convey information, and regulate gene expression. Their ranks include molecules as diverse as antibodies, enzymes, and hormones, so when something goes wrong with proteins, it can be a serious problem.

"Almost all diseases involve some sort of a malfunction of proteins," says Amy Keating, the Jay A. Stein Professor of Biology and head of the Department of Biology. Keating's lab designs protein-protein interactions that could potentially be harnessed for drug therapies.

There are about 20,000 different proteins in the human body, circulating in any given cell by the millions. All start with the cell's own DNA. Individual genes code for specific proteins, and the cell's machinery assembles them from strands of amino acids. These strands then fold in on themselves, settling into specific 3-D shapes as bonds form. This structure is key to the protein's function, including how it recognizes and binds with other proteins in interactions that underlie myriad biological processes.

Keating's focus is on creating proteins that can block interactions that contribute to disease. One way to do that is to alter existing proteins for a specific purpose. If you're trying to make therapeutics, for example, "you might want to make a tight-binding but very selective inhibitor of just the protein that's problematic," Keating says. "You don't want it going off and binding a bunch of other proteins that are actually good for the cell." Keating refers to this kind of tweaking as "redesign."

DNA sequencing and advances in machine learning have dramatically improved researchers' ability to predict protein structure and expand the library of known structures. So, Keating's lab is now trying to move into de novo ("from the beginning") design of proteins, she says. Basically, "if you don't have a good solution already from nature, can we invent one?"

Keating is optimistic. "The rate of progress has just accelerated I think a hundredfold from what it was just two years ago," she says. "Great things are going to happen."
—Robin Kazmier SM '17

(↗)

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spectrum.mit.edu/keating

New Recipes for New Materials

Researchers model better ways to create compounds

Elsa Olivetti PhD '07 and Rafael Gomez-Bombarelli pair computational design techniques and machine learning to assess materials and determine if they can be improved.

PHOTO: SARAH BASTILLE PHOTOGRAPHY

What if we could improve the environmental impact of the products that run our world, from the catalysts that drive chemical reactions to the cement used in buildings and many things in between?

Materials scientists at MIT are asking and answering this very question. Elsa Olivetti PhD '07, the Esther and Harold E. Edgerton Associate Professor in materials science and engineering, and Rafael Gomez-Bombarelli, the Jeffrey Cheah Career Development Professor and assistant professor of materials science and engineering, are leading a collaboration that pairs cutting-edge computational design techniques with machine learning to assess the properties of materials and to determine how they can be redesigned and improved, or if entirely new materials could be synthesized to do a job better.

"We aspire as people that work on matter and atoms to use computational tools in the same way as engineers in other specialties," says Gomez-Bombarelli. Mechanical engineers, for example, use programs such as AutoCAD and Ansys to predict how various components will perform in different environments, and chemical engineers use Aspen to understand processes flows.

Now, Olivetti and Gomez-Bombarelli are bringing similar design tools to the field of materials science and applying them at a broad scale. "We can think about what elements to include in a material and do so with a set of tools that inform design across its life cycle, from manufacturing to recycling," says Olivetti. "That accelerates the screening of materials that might be more sustainable and directs efforts experimentally."

Olivetti, a MacVicar Faculty Fellow, and Gomez-Bombarelli have worked with their students to assemble a suite of machine learning-based software tools, ranging from natural language processing tools to custom neural networks adapted to use molecular structures as inputs. This suite of tools automatically collates information from published literature and uses volumes of data to develop algorithms for materials synthesis and optimized performance.

The team has been using this process to build better zeolites, a class of materials commonly used in catalysts, chemical filters, and the catalytic converters used to clean vehicle emissions. "We use our tools to extract massive amounts of data from the literature around zeolites," says Olivetti. "Then we use our predictive modeling algorithm to determine potential subsequent ingredients to add to make the final zeolite."

Using this system, the researchers were able to work with colleagues to design a new zeolite recipe optimized for removing nitrogen oxide, a major pollutant, from diesel engine exhaust. "We were able to use all this computation to support our collaborators in the lab and hit a narrow, really exciting piece of innovation that would have been really hard to find with traditional trial and error," says Gomez-Bombarelli.

More sustainable concrete

Predictive synthesis works well in cases such as zeolites, in which there are far too many options to sift through experimentally. It's also useful when optimizing a mixture of materials is needed to make a product more sustainable.

Consider cement, an essential ingredient of concrete. Thirty billion tons of concrete is used every year, accounting for 8% of global carbon dioxide emissions due to the intense heat needed to create cement from raw materials such as lime, clay, and silica. Developing a more sustainable process requires a clear understanding of how possible replacement materials might mix.

Because zeolites and cement have a similar chemistry, critical aspects of Olivetti and Gomez-Bombarelli's predictive zeolite work could be applied to the world of cement. The researchers plan to use their techniques to predict how potential concrete ingredients will behave on a molecular level, with the aim of adjusting the recipe to employ, for example, industrial waste materials.

"We use these computational tools to search the space for how to make the best mixture," says Olivetti. "The way I think about it is, how early in the design of new materials can we think about their environmental implications from extraction to end of life?" Her answer? "The earlier, the better." —Stephanie M. McPherson SM '11

"We were able to use all this computation to go into the lab and hit a narrow, really exciting piece of innovation...," Gomez-Bombarelli says.

D-Lab Marks 20 Years of Empowering Communities

Academic program puts tools of design into action around the world

Cooking beans over an open fire used to take hours for South Sudanese refugees living in a camp in Northern Uganda. As the pot sat over the flames, they would have to feed the fire, using up precious firewood and incidentally creating woodsmoke, which harms health and the climate. Recently, however, the refugees began using insulated box cookers; now they can bring beans to a boil for just a few minutes and leave them to cook inside overnight, a system that uses much less energy.

The innovation was made possible by D-Lab, an MIT program that develops collaborative solutions for global poverty challenges. The program, which is celebrating its 20th anniversary this year, doesn't just create products for resource-poor communities; it actively works with people to help them design their own solutions.

"If you are giving people off-the-shelf items, then frequently that means someone else decided what people's priorities are," says D-Lab's founding director Amy Smith '84, SM '95, ME '95, senior lecturer in mechanical engineering. "One of the best ways of knowing what people need is to see what they'll make." The process of teaching design and collaborating to create products ensures that those products will be useful. It is also empowering—especially for people who have been displaced by conflict and are living in camps.

"Being able to feel in control of their environment is something they don't normally have," Smith says. Creating products to fill their own needs fosters "joy and pride."

Above: MIT D-Lab students at the Faros Horizon Center in Athens, Greece, teaching the design process through hands-on learning to refugee youth from Afghanistan, Syria, Pakistan, and Bangladesh.

PHOTO: FAROS HORIZON CENTER

Left: MIT D-Lab Founding Director Amy Smith '84, SM '95, ME '95, shown here in Zambia.

PHOTO: COURTESY MIT D-LAB

Inclusion and equity

Smith became acutely aware of the gulf between the privileged and disadvantaged when she lived in Rajasthan, India, for a year as a child. "Inclusion and equity have always been driving forces for me," Smith says. After studying mechanical engineering at MIT, she joined the Peace Corps in Botswana.

She returned to MIT to earn her master's, intending to develop the skills to design products for communities like the ones in Africa where she worked. As a teaching assistant, she developed classes on designing for the developing world, where resources are limited. "These products are great vehicles for teaching solid design principles of reliability, robustness, and simplicity," Smith says.

After earning her mechanical engineering master's, she continued on as a lecturer at MIT, working with the Haitian Students Alliance to create a course simply called The Haiti Class. Students spent the fall learning about the country, traveled there during the Independent Activities Period in January to conduct research, and spent the spring designing a product. They then returned to implement the solution in summer.

As organizations from other countries learned about the approach, Smith quickly expanded the program to create D-Lab—named in the style of MIT Sloan School of Management classes such as G-Lab, the Global Entrepreneurship Lab. "D is an awesome letter," says Smith, who left the meaning of the initial open-ended. "You can use it for development and design and dissemination and discovery."

Since its founding in 2002, D-Lab has expanded into more than 25 countries, including Colombia, Ghana, India, Mali, and Uganda and involves two dozen MIT faculty and staff. In its 20 years, more than 3,000 students have participated in D-Lab's hands-on, project-based MIT classes, with more than 600 traveling to work with community partners in person.

Today, the program incorporates three overlapping approaches—*design for*, where D-Lab staff works with students to develop technologies for new groups; *design with*, where they create products together with community members; and *design by*, where communities learn to design for themselves. "*Design by* is by far the richest of the three in terms of community development outcomes," Smith says. "It is tremendously empowering and transformative."

In addition to offering more than 15 different classes at MIT each year, D-Lab also helps lead international design summits that bring teams of people together to brainstorm and create new products. It has also developed several curricula that enable partner organizations to teach the principles of design.

In Haiti, for example, Smith and her students helped residents turn agricultural waste into clean-burning fuel. One of Smith's first graduate students, Amy Banzaert '98, SM '06, PhD '13, combined fieldwork and laboratory research to bring the technique to El Salvador and Nicaragua, adapting it to local materials and methods with the help of residents. This laid the foundation for D-Lab's Harvest Fuel Initiative, which later brought the technique to East Africa. Banzaert now serves as director of engineering studies at Wellesley College, where she created "We-Lab," applying D-Lab's collaborative humanitarian approach to domestic challenges.

> "One of the best ways of knowing what people need is to see what they'll make," Smith says.

Respect for people

Other successful products that have emerged from D-Lab include a low-cost water testing kit and pedal-powered machines for washing clothes and processing grain. While most of D-Lab's work has occurred in developing countries, it recently piloted a new project in its Humanitarian Innovation class, which works with displaced people in relatively resource-rich areas. This project centered on teaching design in Greece to unaccompanied refugee children from Afghanistan and Syria.

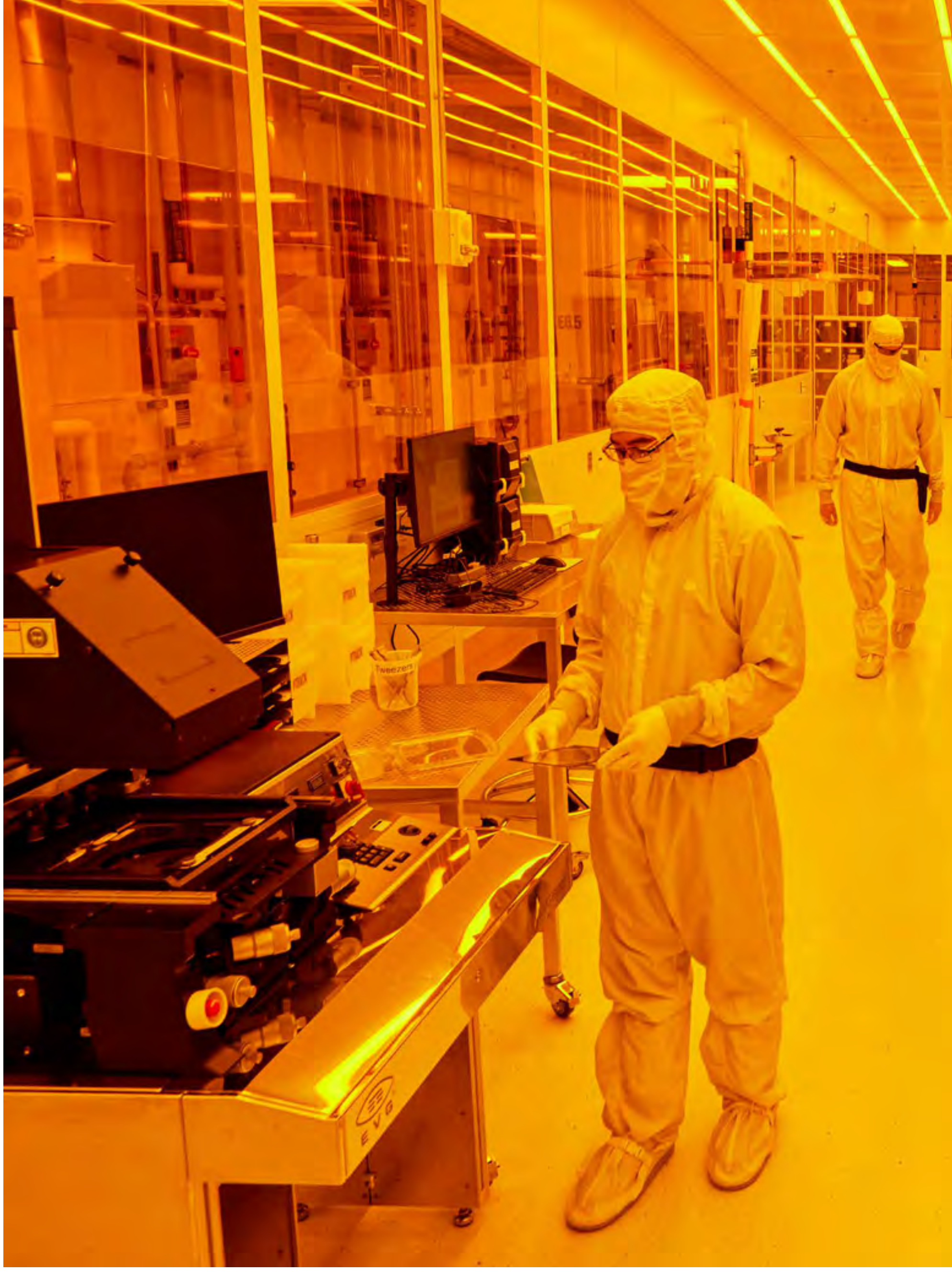
"Some of them came in with the hopes of going into engineering and design and some seemed to be inspired by the work they did at the center," says Sally Beiruti '20, who helped with the project. "It felt like a fun experience for everyone involved."

Beiruti, who is originally from Jordan, now works with an international humanitarian organization and credits D-Lab with solidifying her interest in humanitarian work. "The classes I took taught me to approach work in the humanitarian field with a critical eye because of the unintended harm that can come from well-meaning projects and why the collaborative process is so important," she says.

Ultimately, Smith says one of her goals is to seed "design ecosystems," and she notes that some projects started in D-Lab have spun out into businesses that employ local people to create products for their own communities. Kwami Williams '12, for example, worked on a project helping farmers in his native Ghana to process moringa seeds into high-quality oil. He then cofounded MoringaConnect, a business that provides farmers with financial credit, agricultural training, and other services. "Coming to MIT, I thought my American dream would be working as a rocket scientist," Williams says. "But thanks to D-Lab, I found a global dream, helping the poorest demographic in our world today—rural farmers—improve their lives."

At the heart of everything D-Lab does, Smith says, lies respect for the knowledge and experiences of local people. "We approach people with a very deep level of respect, which they don't always get," Smith says. "They not only appreciate the technology they create, but also the way they are engaged."

—Michael Blanding



A Big Change for the Home of MIT.nano

Alumna Lisa T. Su lends name to Building 12

In May 2022, Lisa T. Su '90, SM '91, PhD '94, chief executive officer and chair of the board of directors of Advanced Micro Devices (AMD), became the first alumna to make a gift for a building that will bear her own name. Building 12, home of MIT.nano, is now the Lisa T. Su Building.

Located at the center of campus adjacent to the Great Dome, the Lisa T. Su Building was constructed to serve as the campus's open-access facility for nanoscale science and engineering. Opened in 2018, the building is notable for expansive glass facades that allow unobstructed views into the laboratories, designed to visually connect researchers within the building and with the world outside. The design of the building has enlivened its shared experimental facilities, drawing the participation of researchers from more than three dozen departments, labs, and centers, as well as external users from industry, academia, and other organizations.

Inventing the future

"Nanoscience and nanotechnology are central to the work of MIT, and to the work of inventing the future," says MIT President L. Rafael Reif. "Through the superb research and training spaces inside its walls, Building 12 brings together many kinds of 'brilliant'—students, faculty, and research staff; scientists, inventors, and entrepreneurs—in spaces deliberately designed to trigger conversation, spark collaboration, and create community."

Vladimir Bulović, the Fariborz Maseeh (1990) Professor of Emerging Technology and founding director of MIT.nano, notes that Su's legacy at MIT began as soon as she graduated. "For many years after her graduation, Dr. Su's technical recipes developed during her PhD studies were followed by new student researchers utilizing MIT's shared toolsets for nanofabrication," he says.

During her time at MIT, "She taught, mentored, and inspired her classmates," says President Reif. "Now well-known, admired, and respected as a visionary leader for her transformation of AMD, Lisa Su is enabling MIT.nano to expand the boundaries of research and innovation at the nanoscale."

An extraordinary career

In 2021, Su led the multinational semiconductor company AMD to its strongest performance in its more than 50-year history, bringing to market several leading-edge technologies. She previously served in multiple roles at Freescale Semiconductor, IBM, and Texas Instruments. Her remarkable career continues MIT's legacy of educating leaders in the semiconductor industry. Su's predecessors include Ray Stata '57, SM '58, cofounder of Analog Devices; Cecil Green '24, SM '24, cofounder of Texas Instruments; and Irwin Jacobs SM '57, ScD '59, cofounder of the global telecommunications firm Qualcomm.

Two of the many honors Su has received include the Global Semiconductor Association's Dr. Morris Chang Exemplary Leadership Award, named for Morris Chang '52, SM '53, ME '55, founding chairman of the Taiwan Semiconductor Manufacturing Company, and the Robert N. Noyce Medal, the highest honor awarded by the Institute of Electrical and Electronics Engineers. Robert Noyce PhD '53 was a cofounder of Intel and the first person to make

Right: Building 12 houses shared experimental facilities that draw researchers from across MIT as well as from industry, academia, and other organizations.

PHOTO: ANTON GRASSL/ COURTESY OF WILSON ARCHITECTS

Left: One of MIT.nano's two capacious clean rooms in which the air is scrubbed of dust and other contaminants that could disrupt research at the nanoscale. The amber light prevents stray UV rays from interfering with nanolithography.

PHOTO: KEN RICHARDSON

Below: Lisa T. Su '90, SM '91, PhD '94 and Vladimir Bulović, the Fariborz Maseeh (1990) Professor of Emerging Technology and founding director of MIT.nano.

PHOTO: SARAH BASTILLE PHOTOGRAPHY

"Nanoscience and nanotechnology are central to the work of MIT, and to the work of inventing the future," MIT President L. Rafael Reif says.

a monolithic integrated microchip. Su was the first woman ever to receive the Noyce Medal.

"I am deeply grateful for the impact that MIT has had on my education and training, and I am honored and extremely happy to be able to impact the next generation of students and researchers," says Su. "There is no substitute for hands-on learning, and my hope is that MIT.nano will enable and develop the best and brightest technologists and innovators of the future."

An active member of the MIT community, Su has participated in several alumni committees, and she gave the Commencement address at the Institute's 2017 Investiture of Doctoral Hoods. She served on the Electrical Engineering and Computer Science Visiting Committee for 10 years and is currently a member of the MIT President's CEO Advisory Board. In 2018, she established the Lisa Su Fellowship Fund, which supports female graduate students who have demonstrated progress and accomplishments in nanotechnology.

"It is wonderful that Lisa Su's name will now adorn the home of today's open-access laboratories and inspire the generations of students who enter the building to follow in her footsteps," says Bulović. –Christine Thielman

VICTOR AMBROS '75, PHD '79 AND ROSALIND "CANDY" LEE '76

Building STEM Opportunities

When Victor Ambros '75, PhD '79 and Rosalind "Candy" Lee '76 began to think seriously about philanthropy, one of their goals was to help boost the diversity of people pursuing STEM (science, technology, engineering, and math). Their alma mater seemed a natural place to direct their resources. "MIT has a history of really pushing and innovating in this area, while a lot of places are just starting to realize that diversity is important," says Candy. "MIT is never complacent; it's always trying to do better."

Hoping to make STEM education available to young people from diverse backgrounds, they were intrigued by a program at MITES (MIT Introduction to Technology, Engineering, and Science) called the MITES Semester, which selects rising high school seniors from all over the country to participate in a seven-month academic and enrichment experience. The majority of the middle and high school students participating in programs at MITES, formerly known as the MIT Office of Engineering Outreach Programs, each year are members of under-represented minority groups.

The couple wanted to support programs with measurable results, so both were impressed when MITES Executive Director Eboney Hearn '01 and her staff were able to answer detailed questions about the efficacy of MITES Semester and other MITES programs, taking the time to explain social science research terms with which they were unfamiliar. "They went through a tremendous effort to engage with us," recalls Victor.

Victor and Candy chose to support MITES because they believe many talented high school students who would thrive in STEM lack access to educational and career opportunities. "We were looking for a program where if we donated funds it would make a lot of difference for individual young people," says Victor. Their first gift to MITES Semester expanded the number of spots in the program by 25% from the prior year, an increase of 25 students. Since Victor and Candy are both scientists in the Program in Molecular Medicine at UMass Chan Medical School in Worcester, they encouraged MITES leadership to consider students from their city, and were grateful that staff took the time to meet with students at every Worcester high school.

Both of them recognize the power of mentorship in STEM, particularly for first-generation students who "may not know how to navigate things like applying to college and choosing a major," says Candy. Victor notes that MITES provides structured mentoring to help students with these processes and also offers programming for students' families. "This kind of support was always there for a select few," says Victor. "The point is to try to provide resources and awareness to everybody, not just a few."

As Victor and Candy approach their 50th undergraduate reunions (Victor's in 2025, Candy's in 2026), they are pleased at how MIT has evolved in many ways since they were at the Institute. For one thing, Candy points out, her class was only 10% female, compared to 48% for the 2021–22 academic year.

A visionary leader and MIT's evolving mission

"The idea of MIT as a community has also evolved over the years, thanks to a series of presidents who encouraged that shift," says Victor. Candy points to former Institute President Charles M. "Chuck" Vest as particularly transformational, adding, "Across the campus there has been a changing awareness that MIT as an institution has a responsibility to the world and that students need support. We've become very proud of MIT."

In addition to MITES, they support the Middle East Entrepreneurs of Tomorrow (MEET), a student-founded program that sends MIT student instructors to Jerusalem in the summer via the MIT International Science and Technology Initiatives (MISTI). The instructors lead classes, groups, and projects that include equal numbers of male and female students as well as equal numbers of Palestinians and Israelis. Although they live within a few miles of each other, this is a unique experience for the students, who continue working together during the academic year with remote help. MEET's mission aligns well with Victor and Candy's goals, as the organization promotes STEM education while creating a community of future leaders who can work together in the face of historical differences.

"We want other alumni to know that the development office can help you find programs that resonate with what you want to accomplish," says Victor. Candy agrees. "We are so grateful to be involved."

—Christine Thielman

PHOTO: SARAH BASTILLE PHOTOGRAPHY

The 1,200-seat large theater in Kresge—named for Lord Swraj Paul PC '52 and his late son Angad Paul '92—hosted the 20th Annual Cancer Research Symposium, presented by MIT's Koch Institute for Integrative Cancer Research, in June 2022, one of more than 100 major events that take place in the iconic building every year.

PHOTO: SARAH BASTILLE PHOTOGRAPHY

LORD SWRAJ PAUL '52

Stage Is Set for a Lasting Legacy

Throughout his life, Lord Swraj Paul '52 has risen to meet diverse challenges. His company, Caparo Group, which he founded in 1968, has gained global recognition. He is a longtime philanthropist and was an advisor, as member of the Privy Council, to the late Queen Elizabeth II.

Looking back, what is his takeaway from these experiences? Gratitude is key.

"I received a great education. And I'm ever so grateful," says Paul, who grew up in British-ruled India at a time when attending college in the United States seemed almost unfathomable. "During my time at the Institute, I saw how education was infused with the ethic of public service, and I applaud MIT for its continuing commitment to these ideals."

In 2020, he made a gift in support of the landmark, Eero Saarinen-designed Kresge Auditorium, MIT's premier venue for world leaders, renowned musicians, distinguished speakers, and faculty and student presentations. The 1,200-seat large theater has been named the Lord Swraj Paul PC '52 and Angad Paul '92 Theater—or, more colloquially, the Paul Theater—after Paul and his late son, Angad, who graduated from MIT in 1992. His son Akash Paul SM '81 also attended MIT.

"MIT means a lot to our family, and I am honored that we are able to support the continuation of its values and way of life through this iconic building," Paul says.

—Joelle Carson

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BRAINS ON THE MIND

This year, The Picower Institute for Learning and Memory celebrates 20 years since Barbara and Jeffry Picower made their transformative naming gift. Today it is a community of more than 250 people dedicated to studying the mechanisms underlying healthy brain function and disease. Here, Gloria Choi (standing), the Mark Hyman Jr. Associate Professor, discusses a set of tissue sample slides with lab manager Natalie Soares.

PHOTO: WHIT WALES/ENDEAVOR FILMS

FOR A BETTER WORLD