Spectrum

Massachusetts Institute of Technology

Fall 2019

Left: Danielle Gleason '20 and graduate student Trang Luu '18 in the MIT D-Lab workshop, where students prototype technologies for the developing world.

PHOTO: SARAH BASTILLE

Wide Angle

Subjects

SPECIAL SECTION

Making

Breakthroughs and Insights

Inside the MIT Campaign for a Better World

FRONT COVER

ILLUSTRATION: ADAM SIMPSON

Fall 2019

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Contact Us
617.253.2066
spectrum@mit.edu

spectrum.mit.edu
betterworld.mit.edu
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Vice President for Resource Development
Julie A. Lucas

Executive Director of Communications and Events
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Director of Marketing and Communications
Aimée Jack

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Managing Editor
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Design
Stoltze Design

Contributing Designer
Niki Hinkle

Copy Editor
Evanthia Malliris

Spectrum Online
Stephanie Eich

The Office of Resource Development gratefully acknowledges the leadership of the MIT Corporation in the MIT Campaign for a Better World.

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Making the Future

As Professor Marty Culpepper SM '97, PhD '00 tells it, he spent his childhood breaking things. Most of the time, he put them back together. When he was 11, he took apart his father's carburetor—without permission, it turns out. Despite his best efforts to return it to good working order, he was left with a few mystery pieces. I expect this was hard on Marty's parents, but his obsession with how things work will sound familiar to nearly any MIT graduate—and it's a perfect qualification for his role as our "maker czar."

We are a community of makers. I think of this every August when I walk past the East Campus roller coaster. Or when the sun hits one of the glass pumpkins in my office. Or when 2.009 (Product Engineering Processes) takes over Killian Court with a fleet of homemade catapults.

With more than 130,000 square feet of makerspaces spread across campus, MIT is a playground of possibility for people who like to work with their hands. If you fondly remember the drill press and bandsaw in the Hobby Shop, don't despair! Those tools are still there. We've just added to the collection. Our students and faculty use the campus's tools to test, explore, prototype, refine, and perfect their ideas—and demand keeps growing.

MIT plans to convert the Metropolitan Warehouse, a massive brick structure at the corner of Massachusetts Avenue and Vassar Street, into a spectacular new home for two entities: the School of Architecture and Planning and a new makerspace, the largest on campus, which will boast expanded design and fabrication facilities available to the entire MIT community.

Our maker czar is leading the way. Together with student volunteers, he is spearheading Project Manus, an Institute-wide effort to create the gold standard in next-generation academic makersystems.

Learning by doing has defined the Institute from the start. It is central to our work to understand the world and make it better. That will never change. We are thrilled about advances our community is making in computing and artificial intelligence, but we will always retain a deep appreciation for the physical—things we can touch and feel and make, and even break—with digital innovation enhancing physical making, and vice versa.

Stay tuned, because at MIT we are always optimizing the prototype.

Sincerely,

L. RAFAEL REIF

MIT (🌍)
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What a Drone Sees

Drones go almost everywhere these days, providing access to places too dangerous or remote for people to explore. They support disaster relief efforts and military reconnaissance missions, and they document the impact of climate change by monitoring the intensity of storms, counting endangered wildlife, and photographing beach erosion.

Unfortunately, drones often crash, damaging costly equipment and stalling research, according to Sertac Karaman SM '09, PhD '12, associate professor of aeronautics and astronautics at MIT. To reduce failure rates, Karaman and his team use virtual reality (VR) to train drones, simulating environments that unmanned vehicles might encounter in the real world. They call this VR training system for drones "Flight Goggles."

The drones programmed by Karaman and his colleagues "see" a world rendered as if in three dimensions—like a video game. The drone learns how to navigate in this environment without the risk of colliding with physical objects.

In reality, the drone is flying in what looks like a big empty gymnasium—a state-of-the-art testing facility made possible by the 2017 renovation of Building 31, one of MIT's oldest research buildings. Outmoded workshops and labs were transformed into custom-designed space for research in robotics, autonomous systems, energy storage, turbomachinery, and transportation. The top-to-bottom modernization also added more than 7,000 square feet of usable space for students, faculty, and researchers.

Karaman has lofty goals for his drone technologies; for example, saving more lives in disaster response work. "So many people lose their lives in the first 15 or 20 minutes after a natural disaster," he points out. "If you could locate them sooner, tell rescuers where they are, you could save more people."

While the human brain can process an astonishing amount of information, he observes, in an emergency, our split-second decisions are often wrong. "Imagine a system that can make those decisions for you," Karaman says, noting that autonomous super-vehicles promise to have maneuvering and navigation capabilities that go far beyond today's human-piloted or human-driven vehicles. "That's an innovation that will save as many lives as the invention of the seatbelt."

IMAGES: COURTESY OF SERTAC KARAMAN (VIRTUAL INTERIOR BUILDING); JOHN ALEMAN (DRONE); VARUN MURALI (CONTROL ROOM)

In this Flight Goggles scene, the drone "sees" an abandoned factory at sunset. The colored windows provide an obstacle course for the drone to fly through.

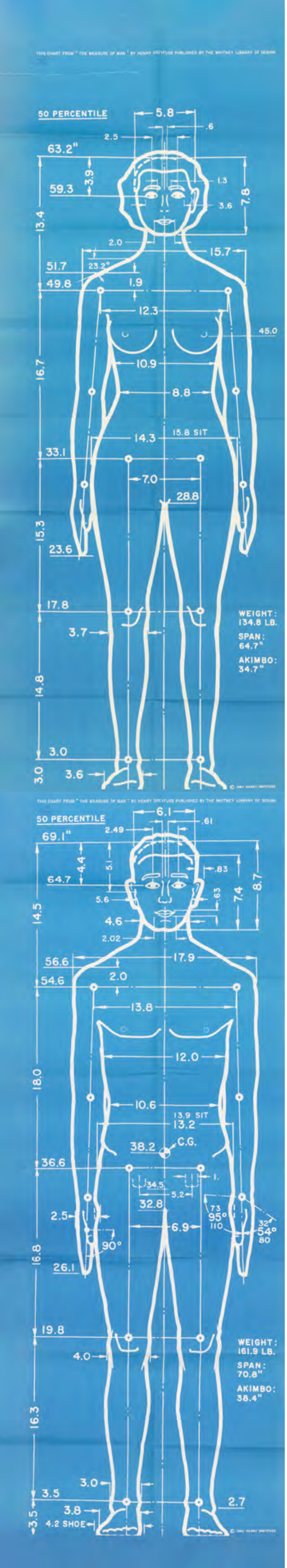
CONTROL ROOM

Flight Goggles researchers monitor the performance of their drones from this control room in Building 31. The building underwent an extensive makeover in 2017 to provide custom-designed robotics research space, including this virtual reality training facility.

MOTION-CAPTURE CAMERAS

In the real test space, motion-capture cameras record the drone's flight and provide feedback. This enables the drone to learn from its mistakes—without crashing.

Equipped with a custom-built super-computer and camera, this drone processes images at a rate of 300 frames per second—more than three times as fast as the human eye.



A Deep Dive into Design

Class brings perspective to the creative process

TITLE

4.657: Design: The History of Making Things

INSTRUCTORS

Timothy Hyde
Clarence H. Blackall Career Development Associate Professor, Department of Architecture

Kristel Smentek
Associate Professor, Department of Architecture

FROM THE CATALOG

The term "design" has many meanings, but at its core it refers to the human capacity to shape the environment we inhabit. Design is as old as humanity itself, and studying its history provides a way to think critically about the past through the lens of design.

The course asks: How have the processes and products of design been shaped by new technological possibilities, whether the discovery of silk, the invention of the automatic loom, or the development of the computer? What role has design played in globalizing capitalist consumer desire, and how, in turn, has it been mobilized in the service of alternative economic and political systems? What are the **ethics of design** in an age of inequality and environmental crisis? Finally, how have the meanings we assign to design been mediated by magazines, exhibitions, corporate communication, glossy design monographs, and advertising?

Hyde: "Ethics of design means asking *why* you're designing something. Not 'what is the purpose or the function of this object' but what are the consequences of something you're making."

THE LECTURES

Students enrolled in Design: The History of Making Things come together for two lectures and one recitation (led by a teaching assistant) every week. Through these meetings, students learn about the process, history, and **social implications** of design. The course aims to create a critical thinking environment, challenging the students to explore not just design success but also missteps and unintended consequences throughout history.

Edwin Song '22: "The question of what is good design also brings up questions about who it's designed for and is this design ethical.... It's way more complicated than someone might think."

In the lectures and discussions, students explore every aspect of design—from the development of pigments to the manufacturing chain behind any given object. They investigate how changing societal norms and economic pressures have affected both the process and result of design. Each class explores the history of a different design industry, including fashion and city planning, for example, and things as seemingly mundane as the chair.

"Chairs have a very long history, but that history is not just how to seat oneself comfortably. For a long time it was not about comfort at all, it was about status," says Associate Professor Kristel Smentek. "There are gender considerations as well. We talk about the models that designers used in the mid-20th century—the standard, normative 'Joe' and 'Josephine'—that determined design of furniture for most of us who don't look like Joe or Josephine."

Students in 4.657 learn that all chairs are not created equal and that not everyone fits the "Josephine" and "Joe" standards that were created for 20th century furniture (far left schematic).

IMAGES AT LEFT: COOPER HEWITT, SMITHSONIAN DESIGN MUSEUM/ ART RESOURCE, NY

“Exposing MIT students to historical and theoretical thinking about design,” Hyde says, “will make them better students, better engineers, better scientists, better citizens.”

THE ASSIGNMENTS

Design: The History of Making Things fulfills one of MIT’s undergraduate CI-H (Communication Intensive in the Humanities, Arts, and Social Sciences) requirements. Over the course of the semester, students complete two major communications-focused assignments.

Students select an item important in the **history of design**, which will become the focus of their assignments. First, each student creates and presents an oral pitch about the object from the perspective of its inventor or investor. This requires that the student evaluate the object’s function and place within its time. The second assignment has each student take a more critical, historical perspective by writing a museum catalog entry for the same item. The goal is to get students to understand the myriad decisions and thought processes that go into designing something for human use, and to analyze from a modern perspective how the making of things has changed over time and from **culture to culture**. At the end of the semester, students complete a take-home final.

Sophia Mittman ’22, on her project item American Modern dinnerware by Russel Wright: “It became such an iconic symbol in the 1950s.... It helped to transform the idea of American home lifestyle, linking it to a more leisurely lifestyle instead of a prim and proper European one.”

Hyde: “This is a novelty that we’re rediscovering in advanced consumerist societies, the idea that you can make stuff for yourself. For four billion other people, this is just daily life.”

GUEST LECTURERS

Each semester, guest lecturers provide students with additional perspectives on design from around the world. For example, last year, one lecturer discussed the thought processes involved in **design behind the Iron Curtain**, presenting a counterpoint to design in a Western, capitalist framework. A speaker from the MIT Museum talked about the MIT Office of Design Services, a woman-led graphic design studio (1960s to 1980s) that led the world in bold graphic design concepts. Dietmar Winkler, who worked in the Office of Design Services, also spoke about the group and its impact. And students heard from an artist who designs objects and social spaces with an eye to accommodating the disabled—revealing how deliberate design choices can transform social situations.

Smentek: “Design decisions were driven by ambition to forge a new society—a classless society—by transforming chairs, cups, and clothes” in ways that would downplay social division.

All the lessons raised in Design: The History of Making Things mesh together to teach students that every decision has **consequences**. As Smentek says, “Problem-solving can also simultaneously be problem-producing.” For example, the advent of plastics has both provided convenient packaging and generated a lot of pollution.

Mittman: “Everywhere you look, wherever you are...there is some aspect of design that has an entire history behind it.”

Students come away understanding they can make a difference by taking a longer, deeper view of the design process when creating things in their own lives. “Exposing MIT students to historical and theoretical thinking about design, about objects, about engineering, about making will make them better students, better engineers, better scientists, better citizens,” Hyde says.

—Stephanie M. McPherson SM ’11

CHAIRS: COURTESY OF KNOLL, INC. (ABOVE LEFT); © ADAM NOWAK / DREAMSTIME.COM (LEFT); SKODONNELL (RIGHT)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MAKING

Making has always been at the heart of an MIT education. The Institute's motto, "mens et manus" (mind and hand), reflects this educational ideal, which harnesses creativity, intellect, and craftsmanship for practical application.

Today, MIT is embracing the mission of making with more fervor than ever.

As MIT "maker czar" Martin Culpepper says, "Taking something that exists in your head and making it pop up in the universe—that's the first step toward having an impact."

From left: Professor Martin Culpepper SM '97, PhD '00 works with Sabrina Hare '22 and Charlie Garcia '19 in The Deep, a makerspace in Building 37.

PHOTO: SARAH BASTILLE

Fostering Creativity

Makerspaces across campus invite tinkering and spark joy

In the basement of Building 37, a small red logo spray-painted on a wall points you to The Deep: subterranean rooms lined with machines sprouting gears and dials and bits that slice, sculpt, etch, vacuum-shape, burn off layers, or deposit material microns at a time.

Any day of the week you can find students signing in on iPads, donning safety glasses, and getting to work making things. Encouraging such creativity is the idea behind Project Manus, an Institute-wide initiative to upgrade makerspaces on campus and foster maker communities, building on MIT's long history of inventiveness and the maker spirit embodied by the aproned craftsman pictured on the Institute's seal.

Heading up the project is maker czar Martin Culpepper SM '97, PhD '00, professor of mechanical engineering. In his Building 35 laboratory, Culpepper creates new precision machines for manufacturing and robotics. At home, he makes, among other things, gourmet meals and gadgets for his Ducati motorcycle.

He believes MIT students get their hands dirty to make a difference. "The vast majority of students come here knowing there's a high probability they'll be able to do something meaningful," he says. "Taking something that exists in your head and making it pop up in the universe—that's the first step toward having an impact."

Alejandro Gonzalez-Placito '20 mentors other students working in The Deep, a maker-space in Building 37.

State-of-the-art facilities

All across campus, undergraduate and graduate students create with serious intent: researching new ways to deliver drugs to cells, for example, or to collect samples from deep within the Earth's core. They design interactive music systems, build new economic modeling tools, and cast unusual components for buildings. Hands-on, project-centered curricula are part of the DNA of MIT and one reason the Institute has spawned so many imitators around the globe.

Beyond the classroom, students make things for fun, stress relief, or art—simply because they can. In 2015, Culpepper surveyed thousands of students about their personal approaches to making. Some of the responses surprised him: Men and women coveted access to hard-core machinery in equal numbers, and many students—in addition to writing code, building electric vehicles, and blowing glass—liked to cook gourmet meals.

"These makerspaces ground people in an appreciation of what it takes to make something," Schmidt says.

Sofia Leon '22 makes an electric scooter in MITERS, a machine shop in Building N52.

Project Manus emerged to give students—many of whom were making things in their dorms or off campus—access to state-of-the-art facilities for whatever they want to make, and a nexus for like-minded people to come together to work on projects and solutions across different disciplines.

In 2018, Alejandro Gonzalez-Placito, now a senior studying art and product design in the MIT School of Architecture and Planning, saw a flyer about Project Manus. He ended up helping to build out the basement space that became The Deep. Growing up in Denver, he'd made both useful and frivolous things out of scraps from his dad's woodshop. Now, he's one of dozens of student mentors populating makerspaces around campus.

The makerspaces themselves are also many and various. For example, in addition to The Deep, there's the Hobby Shop, a popular wood and metal shop in W31; ProtoWorks, an "entrepreneurial ecosystem" that supports everything from software to projects in clay and foam; and the MIT Electronics Research Society (MITERS), a machine shop in N52 run by a dynamic community of students and alumni that has spawned startups such as Kitty Hawk, which is developing flying cars. MakerWorkshop, a student-run makerspace, enables users to prototype new parts or devices, and MakerLodge in Building 6C is geared toward getting first-year students familiar with belt sanders, hand tools, 3-D printers, laser cutters, and computer-controlled machining. There's the BioMakerspace, where you could, among other things, develop photos on petri dishes using bacteria, and MIT Student Arts Studio, which cultivates and supports MIT arts-focused entrepreneurial projects and business teams.

Making things has been a core human endeavor since the creation of fire and stone tools, but it's easy to lose sight of this history. Professor of History Anne E.C. McCants recalls speaking in class about the importance of the textile industry in medieval Europe or using the expression "dyed in the wool" and getting blank stares. "My students actually had no idea what I was talking about because the world of spinning wheels and raw materials was so foreign to them," she says.

She started bringing raw, dyed, and carded wool and drop spindles to class for students to examine. For years, she taught a week-long Independent Activities Period class on spinning. She keeps a spinning wheel in her office and students regularly ask her to show them how to use it.

She also joined with fellow historian Jeffrey Ravel, a professor who is currently the head of the History Section, to lead a class that built a hand-set printing press in the Hobby Shop. "I very strongly feel that you can't actually understand economic history without having a sense of the tactile experience of the way people lived their lives," she says.

Such tactile experience is at the heart of Project Manus. In The Deep, Gonzalez-Placito comes up with project kits to help students become familiar with the many tools of making in use today. "We don't expect people to be very rigid and follow every rule step by step, but play around," he says. "Making mistakes is part of this space." He shows a visitor the "wall of learning": a display of broken drill bits, failed vacuum molds, and gnarled green plastic spit out by the 3-D printer.

One student wanted to devise a drink dispenser for a dorm refrigerator; that ended up somewhere in the bowels of Building 37, Gonzalez-Placito recalls. Other projects—a motorized skateboard, a reinforced welded-steel truss for a building technology class, a prototype of a spill-proof breast pump attachment—have been more successful. Gonzalez-Placito says that for himself he's made a 3-D-printed spoon that can be adjusted to any angle, an intricate spiral lamp, and a 3-D-printed Faberge-style egg on a stand.

Ngoc La '21, a student in the Department of Aeronautics and Astronautics, peers inside one of The Deep's 3-D printers as a white rectangular structure takes shape. She is re-creating an adapter for cameras and electronic components associated with Astrobee, a robot developed by NASA that supports astronaut-run experiments on the International Space Station. She estimates that she's at The Deep most weekdays and likes the fact that it's open after 5 pm.

Metal, wood, glass, stone, resin, plastic, leather—whatever medium students choose, Gonzalez-Placito helps them realize their vision. "It's pretty awesome to just make sure that students feel empowered to come and make things," he says. Once they become aware of The Deep, he says, "it sort of liberates them."

Inspired by Doc Edgerton

The walls of a fourth-floor hallway known as Strobe Alley in Building 4 are lined with iconic images—the milk drop coronet, the bird in flight, the exploding apple. There's a faint smoky odor, as if the ghost of inventor Harold E. "Doc" Edgerton SM '27, ScD '31 just fired off a stroboscope.

In the 1970s, when Edgerton's electronic flash was transforming photography, Forbes Director of the Edgerton Center J. Kim Vandiver SM '69, PhD '75 was his student. Vandiver later worked alongside Edgerton on new ways to visualize the flow of air and water.

"There's story after story after story of students coming to Edgerton and saying, 'Hey, I've always wanted to build something,'" says Vandiver, professor of mechanical and ocean engineering. "And Doc would say, 'There's a workbench and a soldering iron. What are you waiting for?'"

At the time, shops in engineering departments were dedicated to class projects. After Edgerton died in 1990, Vandiver proposed turning his mentor's lab of machine tools, drill presses, soldering irons, and oscilloscopes into a place where MIT students could invent or build stuff just for fun.

The Edgerton Center became one of the first independent makerspaces at MIT, and its legacy continues. Peer mentors, staff, and alumni now offer help with engineering, coding, and more to MIT teams and clubs taking on ambitious international challenges such as designing autonomous racing vehicles and marine robotics. This year, a multidisciplinary MIT student team spent the summer designing and building a prototype for Space X's annual Hyperloop Pod Competition—a challenge centered on propelling frictionless pods through a tube at 800 mph. The group placed first among US university teams.

Building confidence

When Vandiver was growing up, he liked working with his hands. If he wanted to drive his dad's vintage jeep, he had to help maintain it. He learned to tune it and replace the brakes. He built Heathkits (DIY electronics kits manufactured by the Heath Company).

In central Iowa, Culpepper was the same kind of kid. He fixed everybody's bikes and tinkered with machines he found in his grandfather's junkyard. "If things broke, the only way they were going to get fixed was if you did it yourself," he says. More recently, Culpepper's creations have included a mechanism for flushing brake fluid from his motorcycle and laser-cut wall plaques he gave his teenaged kids as gifts.

Not everyone has spent as much time making stuff as Vandiver and Culpepper. Many MIT kids are more comfortable with hacking than hacksaws, and it's not just students who suffer from maker anxiety. Culpepper recalled one time a faculty member and senior administrator balked at trying his hand in a makerspace. "If I said this person's name, you'd be like, that's crazy, but we see it at all levels. It's human nature to not want to look like you're not good at something."

When you make stuff, you mess up. So, how do campus makers coax students out of their comfort zones?

Step one: Mobius. The Project Manus-run Mobius app lets students check in real time which of more than 40 makerspaces are open and available, book spaces and machines, sign up for training, and pay for materials. (ProtoWorks at the Martin Trust Center for MIT Entrepreneurship, MakerLodge, and other spaces also lure students with pizza, coffee, granola bars, and ramen.)

Domenic Narducci '20 and Steven Truong '20 work with bacteria that respond to stimulants by turning different colors. The students are in the BioMakerspace.

PHOTO: SARAH BASTILLE

“Making things is about solving complicated puzzles, working with other people, and challenging yourself,” Culpepper says.

Step two: eye candy. MIT students are very curious, Vandiver says. “If they see something cool, they'll take the time to try to make it themselves.” Students in The Deep, for instance, can copy Gonzalez-Placito's original design for a mold that makes ice in the likeness of Tim, MIT's beaver mascot.

Step three: peer mentors. “One of the biggest strengths we have on campus is a culture of paying it back. Among the student mentors,” Culpepper says, “that's worth way more than any army of 40- or 50-year-old grumpy people like me.

“I want students to leave with the mind-set, ‘I'm going to have to make something eventually, and I'm going to be able to do that,'” he says. “You're building a likelihood that they'll hop on this kind of learning, whether it's programming or machining. Making things is about solving complicated puzzles, working with other people, and challenging yourself.

“It changes you,” Culpepper says. “I would call it confidence.”

MIT founder William Barton Rogers's view that science should fuel innovation and functionality was radical in the late 19th century; makerspaces are now ubiquitous in universities, public libraries, and even storefront studios in local communities. Provost Martin A. Schmidt SM '83, PhD '88, who in 2015 initiated Project Manus, believes “if you don't know how things are made, then you're severely limited in knowing how to make them better or how to make new types of things. These makerspaces ground people in an appreciation of what it takes to make something and helps them think creatively about how to make new things. We see this as an investment in the innovation ecosystem.”

Schmidt and others say it's time for MIT to reaffirm its place as the ultimate makers' playground.

Culpepper says, “It's almost like MIT is this wonderland—a place in the world where students should feel that if they want to build almost anything, they can.” —Deborah Halber

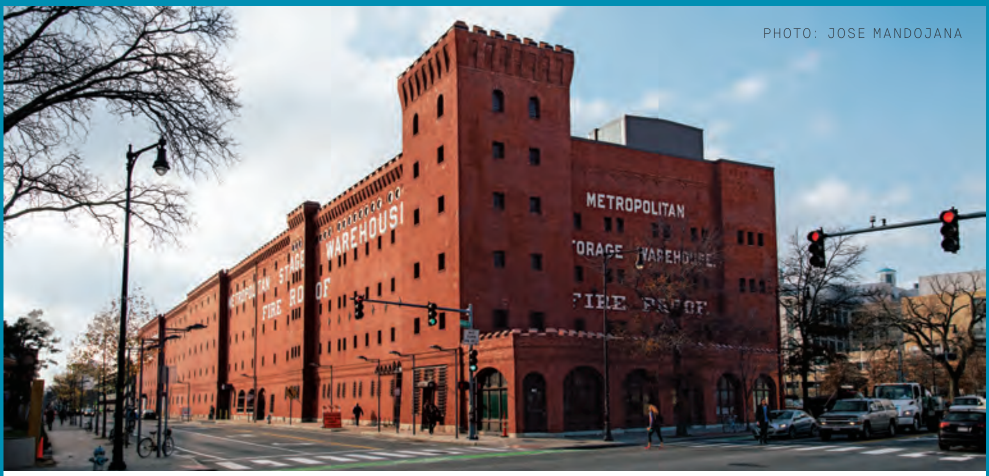


PHOTO: JOSE MANDOJANA

Met Warehouse Renovation to Include Maker Hub

For more than a century, the red-brick Metropolitan Storage Warehouse with its crenellated tower has been a formidable presence at the corner of Massachusetts Avenue and Vassar Street. Now, the historic structure is envisioned as a state-of-the-art hub for the MIT School of Architecture and Planning (SA+P), including a separate, expansive new campus-wide makerspace.

The building, designed by prominent Boston architectural firm Peabody & Stearns and considered to be of high historic significance, has been owned by MIT since 1966. The proposed renovation will preserve much of its historic architecture and distinctive exterior while expanding SA+P's range of activities in design, research, and education.

The renovation will also create the largest makerspace on campus, an approximately 17,000-square-foot facility overseen by Project Manus—MIT's makerspace initiative launched with a gift to the MIT Provost's Office from Cynthia L. Reed and John S. Reed '61, former chairman of the MIT Corporation, and supported by numerous alumni and friends since.

“Our goal is to create a makerspace that will set the gold standard for the next generation,” says Provost Martin A. Schmidt SM '83, PhD '88, who in 2015 launched Project Manus. The Met makerspace will provide a full range of cutting-edge maker tools and supplies—enabling users to create anything from holiday ornaments to industrial prototypes. It will also be the first makerspace at MIT dedicated to making all resources in the space 100% accessible now and in the future.

The location will double the amount of makerspace available to the entire MIT community. It will be “an open-access gathering place for MIT's innovators and makers,” says Martin Culpepper SM '97, PhD '00, director of Project Manus and MIT's maker czar. The Met will be “the big community space where anybody at MIT can build things, and you can hang out with people who want to build anything from research projects to business prototypes.”

Culpepper, a professor of mechanical engineering, likens the Met makerspace to a centralized, free-form innovation nexus: a destination where students, alumni, faculty, and staff of all departmental and school affiliations “can meet and do what MIT community members do best—create.”

The new makerspace is made possible with support from the Victor and William Fung Foundation, founded by MIT alumnus Victor Fung '66, a prominent Hong Kong business and civic leader, and his brother, William.

Through telecommunication technology, the Met makerspace will link to the MIT Hong Kong Innovation Node, a collaborative space that aims to connect the MIT community with unique resources—including advanced fabrication capabilities—and other opportunities in Hong Kong and the neighboring Pearl River Delta.

The Met makerspace “will vastly increase MIT students' access to the resources they require to iterate and drive ideas toward realization and adoption by the marketplace. It will also provide maker training to students and help build an Institute-wide maker community,” Schmidt says. “It will cultivate our students' deep passion for learning, inventing, tinkering, and creating while providing them with new avenues through which to share their potentially game-changing prototypes and visionary projects with the world.” —Deborah Halber

What Are You Making?

Weixun He ’19

MAKING: Robotic bartender

Almost every day this summer, Weixun He practically lived at ProtoWorks, a makerspace at the Martin Trust Center for MIT Entrepreneurship. “Making is very powerful. You learn all these theoretical concepts that are useful, but until you make something, there is so much you don’t know,” he says, noting that in addition to machines, the makerspace provides mentorship and a supportive community. This support has proved invaluable as He works with a startup to develop robotic bartenders—“to make the office more social.” He’s team fabricated its whole working prototype at ProtoWorks. “This room represents the bridge between the physical world and your idea,” says He, who majored in mechanical engineering.

Effie Jia ’20

MAKING: Aluminum sign

An architecture major and design fellow in the MIT Office of Sustainability, Effie Jia is making the sign for a new campus garden. “Making to me is being able to take my ideas as a visual thinker and transform them into tangible, useful products that are beautiful as well,” she says. In one MIT design studio, for example, she worked with Tumi to prototype a new design for luggage. “That was one of the coolest experiences,” she says, adding that making things has been an invaluable part of her time at MIT. “I like to be self-sufficient and to be able to look at something and say, ‘I know how to make that’—that’s a really cool mindset to have.”

Sabrina Hare ’22

MAKING: Map of Barcelona

“I discovered through makerspaces and a lot of the hands-on classes I took freshman year that I really liked making things,” says Sabrina Hare, a mechanical engineering major who is making the map as a reminder of her hometown. “I really like The Deep because it gives you access to intense machinery you aren’t able to access in other shops, like laser cutters, mills, and lathes. There aren’t as many barriers to cross before being able to use them. You go through a general orientation and a specific-machine training and then you can get going.”

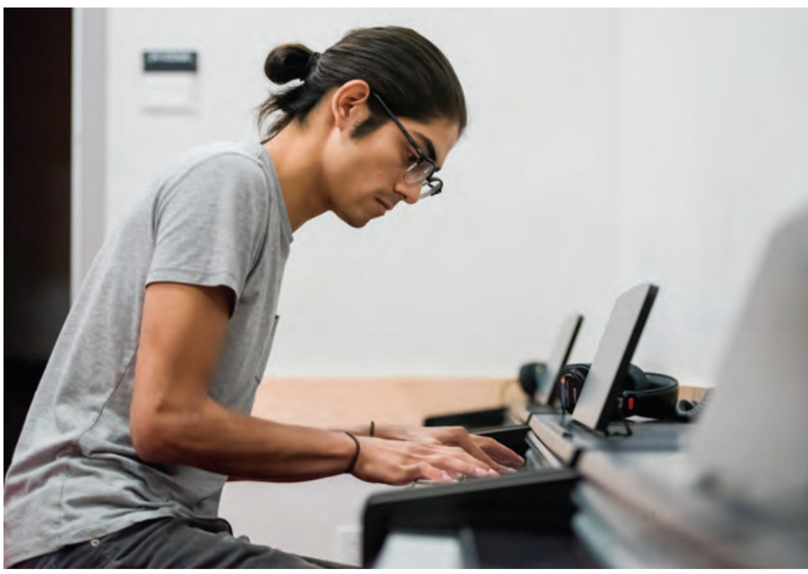
(↗)
MEET MORE MIT MAKERS
spectrum.mit.edu/makers

PHOTOS: SARAH BASTILLE

Bobby Johnston, PhD candidate

MAKING: Machine that makes cocktail ice balls shaped like the Death Star

Physics PhD candidate Bobby Johnston is making the Death Star machine as a gift. "My sister and her husband just got married and I wanted to get them an awesome gift, but being a graduate student I don't have a ton of money to throw around, so I figured I would just build something myself," he says. "I'm pretty psyched with how it has come out." He says working in the MIT Hobby Shop is "incredible." "Most people are only here because they want to be, so everyone is in a really good, helpful spirit. I am happy I found this place."



Juan Carlos Garcia '20

MAKING: Live-streaming app for music program notes

Juan Carlos Garcia is in the Music Technology Lab working with others on ConcertCue, an application that streams program notes to audience members during concerts. "Classical music is dying in popularity, especially among younger people. This is a way to make a more interactive experience," he says. A double major in computer science and music, Garcia says he values the opportunities MIT has given him to put his two passions together. "I'm super happy to be incorporating computer science and music in a way that can help society develop a deeper understanding," he says. "I have a deep appreciation for art and culture and making."

Nora Enright '19

MAKING: Bacterial photography

"People have been working really hard to make the new biomaking space an exciting space that involves the wide scope of bioengineering projects," says Nora Enright, who is making images using bacteria that respond to light. "I think having opportunities to try out these different skills and build projects in a way that other engineering disciplines can do is really exciting." Enright, who majored in biological engineering, believes the experience she is gaining will also help her achieve her ambition of running her own lab someday. "Getting to talk to people who have these amazing ideas and all this passion for what they do and getting to be a part of it is just great."

From Idea to Execution

Trust Center helps myriad startups make the leap

The Martin Trust Center for MIT Entrepreneurship and its flagship delta v accelerator program prepare aspiring student entrepreneurs to launch business ventures when they leave MIT. For three months each summer, select student teams work to make their visions viable—consulting with mentors, attending simulated board meetings, drafting business plans, studying finance options, and conducting market research. At the beginning of the school year, delta v graduates present their work to potential investors at Demo Days at MIT, in New York City, and in the San Francisco Bay Area.

More than three-quarters of the 76 companies the accelerator has launched since 2013 are still in business (or have been acquired). Overall, the accelerator has helped its companies raise more than $151 million. Participant companies produce myriad products, including a smart device that monitors birth control pill consumption, a virtual reality program that promotes cognition and mental health in the elderly, and a trailer that can be towed by motorbike to provide ambulance service in remote, developing regions.

Whatever the product, the Trust Center focuses on helping MIT's makers make their companies work. Here are a few examples.

Xiao Liu, right, a community organizer with Roots Studio, looks over a batik print with an artist from Guizhou, China.

PHOTO: 心奕

Leuko Labs

With a PhD in electrical engineering and computer science, Carlos Castro-González could have worked for a telecom company or designed the newest mobile phone. But, he says, "Solving medical problems seemed more meaningful."

So, as a postdoc at MIT, Castro-González joined the Madrid-MIT M+Visión Consortium (today MIT linQ) a health innovation partnership that would connect him to his three company cofounders: Ian Butterworth, research engineer in electronics at MIT, Álvaro Sánchez-Ferro, a Madrid-educated physician, and Aurelien Bourquard, a Swiss biomedical engineer.

Together, the four developed the technology that launched Leuko Labs—a noninvasive portable device that measures a patient's white cell status and relays the measurement to the cloud, where the data are processed and transmitted to the health care team. Low white cell values, a typical side effect of chemotherapy, can leave patients unable to ward off infection, potentially leading to life-threatening—and costly—hospital readmissions.

The team won a spot in the 2016 delta v accelerator, where they found many of the tools they needed to succeed. "After our summer at the Trust Center, we knew that if our technology was sound, there was definitely a market for it," says Castro-González. "The Trust Center provides you with all the things you need to become an entrepreneur."

Founded in 2018, Leuko Labs currently has nine full-time employees in Boston and Madrid, Spain. The company closed out its seed round of financing earlier this year. Castro-González estimates Leuko Lab's device could save an average cancer center $50 million or more each year.

Roots Studio

Rebecca Hui MCP '18 concedes she was an unusual candidate for the delta v accelerator—but she never once felt out of place. "It was fantastic," says Hui, whose company, Roots

Studio, digitizes the work of artists who live in isolated and distressed regions and licenses those images for consumer products sold in the developed world. “Coming from a cultural space, it was invaluable for us to steep in an environment focused on marketing, manufacturing, and securing funding. The Trust Center forced us to become concrete and take shape.”

An urban planner by training, Hui came to MIT in 2015 after creating and running Toto Express, a school on wheels in India. That project brought teachers to students in rural Bengal villages who were struggling with attending school. The experience heightened Hui’s appreciation for native art and fueled her desire to share that beauty with the world—and to offer indigenous artists a living wage.

Hui’s original plan had Roots Studio digitizing the artwork, printing the images on notebooks and posters, and then distributing those products. Her dorm room was overflowing with notebooks when she started at the delta v accelerator in 2017.

She says the accelerator helped her realize that print products were not the right business track to pursue. “Our core assets were the images and the trust we’d built with the native communities,” she says, noting that the Trust Center mentors “changed the way we thought about process and scale.”

Today, Roots Studio licenses production to companies with scalable manufacturing and existing supply chains. The business has eight full-time employees, more than 40 field workers, and collaborations with more than 1,200 indigenous artists in India, Indonesia, the Middle East, and other regions. The startup also pays artists from 5 to 20 times what they can receive for their work at home.

One long-term company goal, Hui says, is to revive art and craft forms in danger of disappearing. “Many of the artists we meet believe their art forms will die with them,” she says. “We’ve given some of those art forms a market and a future.”

The Martin Trust Center’s flagship accelerator program has helped companies raise more than $151 million.

Lightmatter

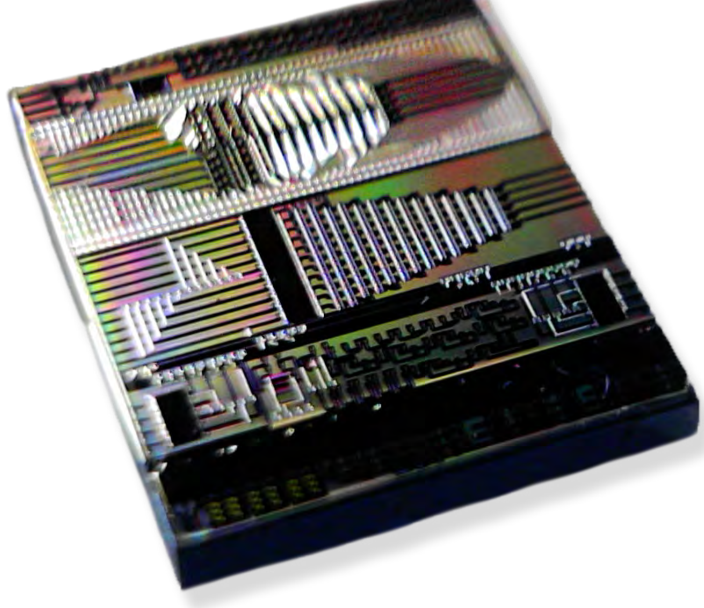
In 2017, Nicholas Harris PhD ’17 and lab partner Darius Bunandar PhD ’19 decided to take a class on entrepreneurship at the MIT Sloan School of Management. They were in the early stage of incorporating photonic components into computer chips that would enable those chips to significantly outperform conventional chips. The pair believed their technology could have widespread applications for deep learning and artificial intelligence.

“We were running into the logical end of Moore’s law,” Harris observed, referring to an early prediction linking the shrinking of transistors to ever-more powerful computer chips. “We thought the introduction of photonics could continue that progression.”

While at the Martin Trust Center, the pair (together with Lightmatter cofounder Thomas Graham MBA ’18) took advantage of the workspace and mentors to prepare for the 2017 $100K MIT Entrepreneurship Competition—which they won. “As scientists, Darius and I had learned to value hard skills, like doing math and solving physics problems,” says Harris. “At the accelerator, we learned the value of building relationships, negotiation, and dealing with people. It was an excellent preparation for the $100K challenge.”

The trio launched their company in December 2017, naming it Lightmatter. The not-yet two-year-old startup has 30 employees and has produced two early chips—the most recent containing over a billion transistors. An early round of financing netted Lightmatter $11 million. Last February, GV, a venture division in Google’s parent company, Alphabet, invested another $22 million in the fledgling venture.

“We’re planning to share a preliminary version of our product with big cloud providers,” says Harris, noting that the company is also shoring up its engineering and business structures. “We should be ready to get to market in the next few years.” —Ken Shulman

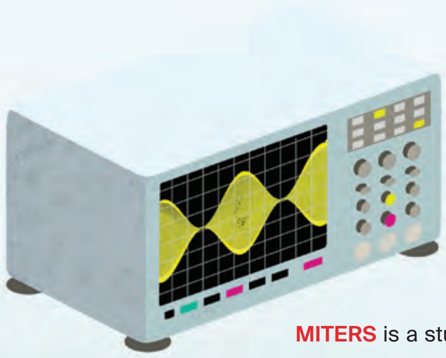


Above: This chip was designed by Nicholas Harris PhD ’17 in 2013. It is a precursor of the integrated photonics work now under way at Lightmatter.

PHOTO: COURTESY OF LIGHTMATTER

Left: This device, developed by MIT startup Leuko Labs, measures a patient’s white cell count without breaking the skin.

PHOTO: COURTESY OF LEUKO LABS

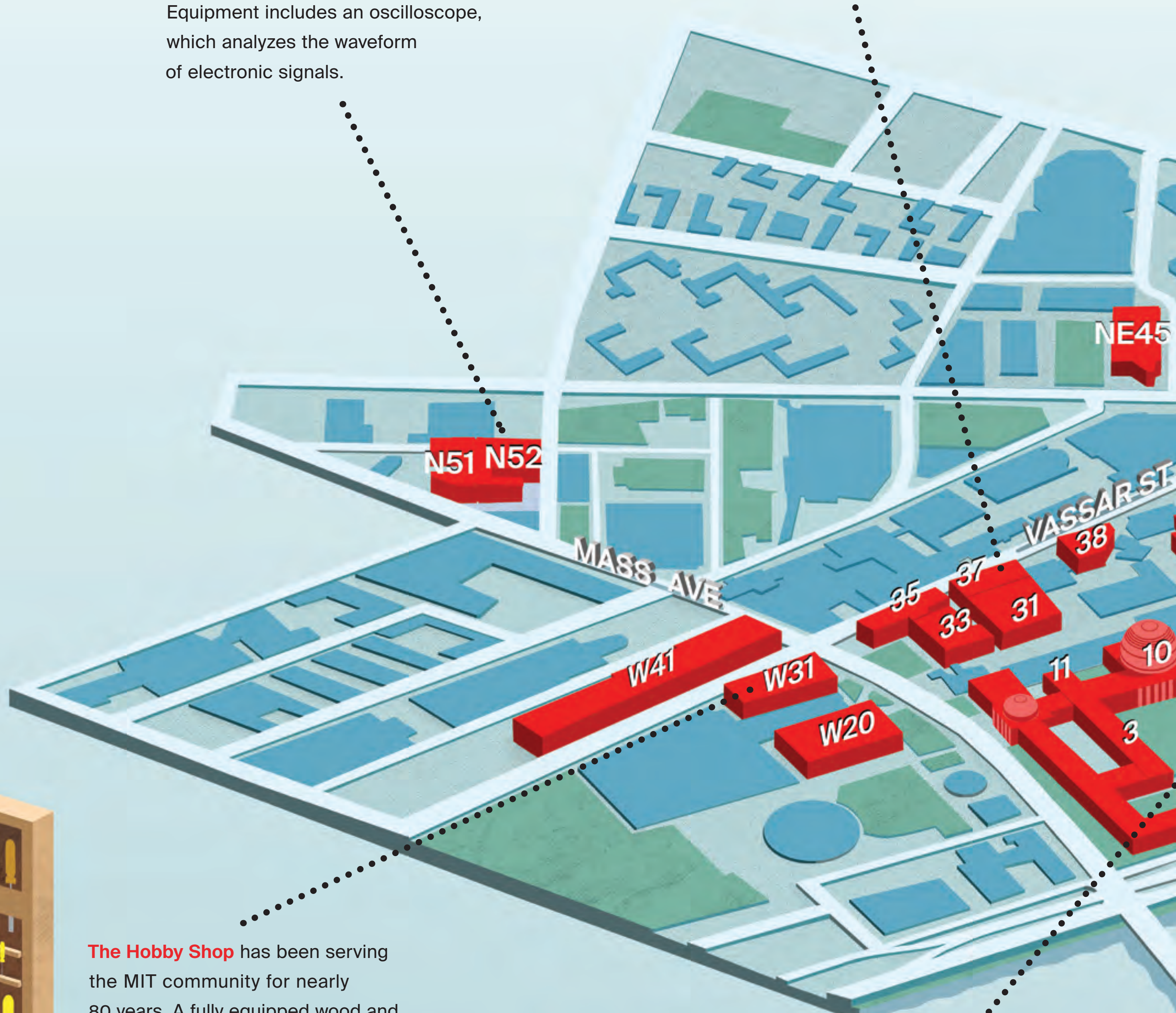


Maker Map

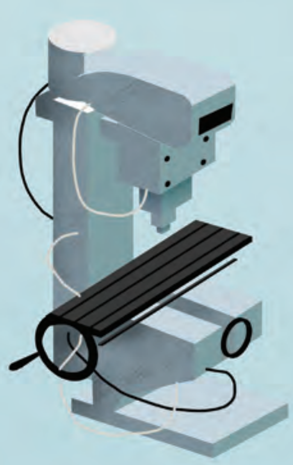
Hands-on project spaces span campus

The Deep is a 1,239-square-foot makerspace where anyone in the MIT community can use tools ranging from simple drills and saws to a computer numerical control (CNC) lathe or waterjet cutter. Students are even welcome to try tungsten inert gas (TIG) welding.

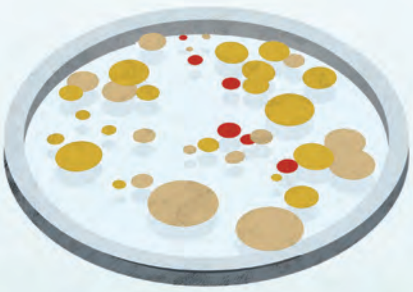
MITERS is a student-member-run project space and machine shop focused on electronics and metal-working capabilities. Equipment includes an oscilloscope, which analyzes the waveform of electronic signals.



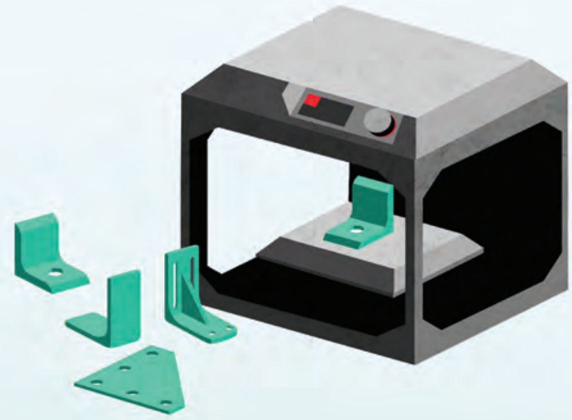
The Hobby Shop has been serving the MIT community for nearly 80 years. A fully equipped wood and metal shop, it is a great place to learn to handcraft wooden furniture—perhaps using a set of chisels.



The Edgerton Student Shop is a machine shop that offers intensive training classes focused on metalworking. Students can, for example, learn to use a milling machine to shape surfaces.



The **BioMakerspace** supports project teams working on long-term research in biology, optics, mechanics, mathematics, electronics, and chemistry. Makers using its extensive laboratory and fabrication facilities can, for example, culture photosensitive bacteria.



Martin Trust Center ProtoWorks is focused on giving budding entrepreneurs a place to create prototypes. It's one of several makerspaces where students can use 3-D printing capabilities.

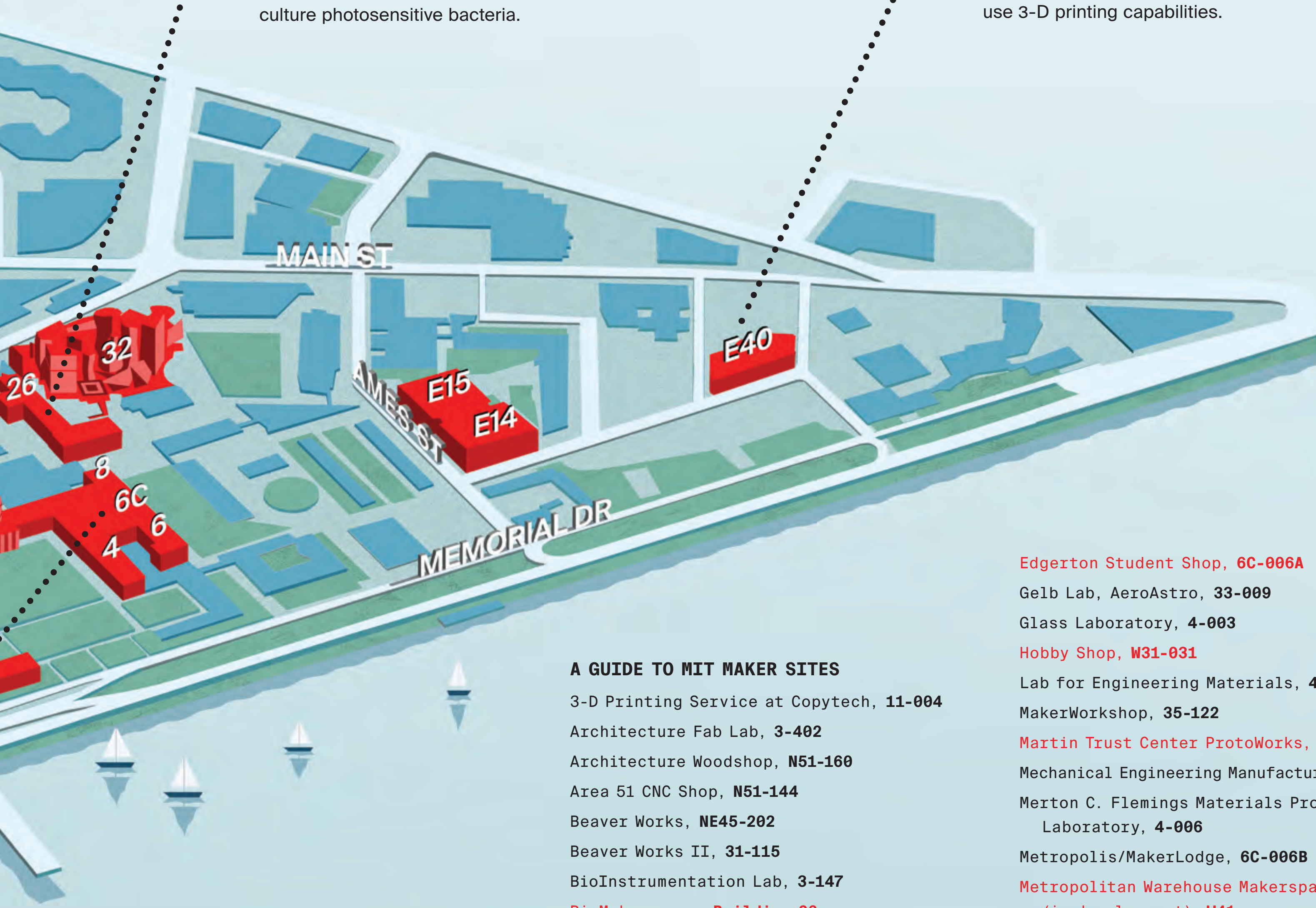


ILLUSTRATION: ADAM SIMPSON

A GUIDE TO MIT MAKER SITES

3-D Printing Service at Copytech, **11-004**

Architecture Fab Lab, **3-402**

Architecture Woodshop, **N51-160**

Area 51 CNC Shop, **N51-144**

Beaver Works, **NE45-202**

Beaver Works II, **31-115**

BioInstrumentation Lab, **3-147**

BioMakerspace, **Building 26**

Center for Bits and Atoms, **E15-151A** and **166**

Chemistry Machine Shop, **4-063**

Computer Science and Artificial Intelligence Laboratory (CSAIL) Machine Shop, **32-242**

CSAIL Woodshop, **32-Mezzanine**

Cypress Engineering Design Studio, **38-501**

D-Lab Workshop, **N51-300CA**

The Deep, **37-072**

Edgerton Student Project Lab, **4-409**

Edgerton Student Shop, **6C-006A**

Gelb Lab, AeroAstro, **33-009**

Glass Laboratory, **4-003**

Hobby Shop, **W31-031**

Lab for Engineering Materials, **4-131b**

MakerWorkshop, **35-122**

Martin Trust Center ProtoWorks, **E40-160**

Mechanical Engineering Manufacturing Shop, **35-125**

Merton C. Flemings Materials Processing Laboratory, **4-006**

Metropolis/MakerLodge, **6C-006B**

Metropolitan Warehouse Makerspace (in development), **W41**

Milk Drop Shop, **N51-318**

MITERS, **N52-115**

Museum Studio, **10-150**

Pappalardo Machine Shop, **3-050**

Physics Machine Shops, **6-214**

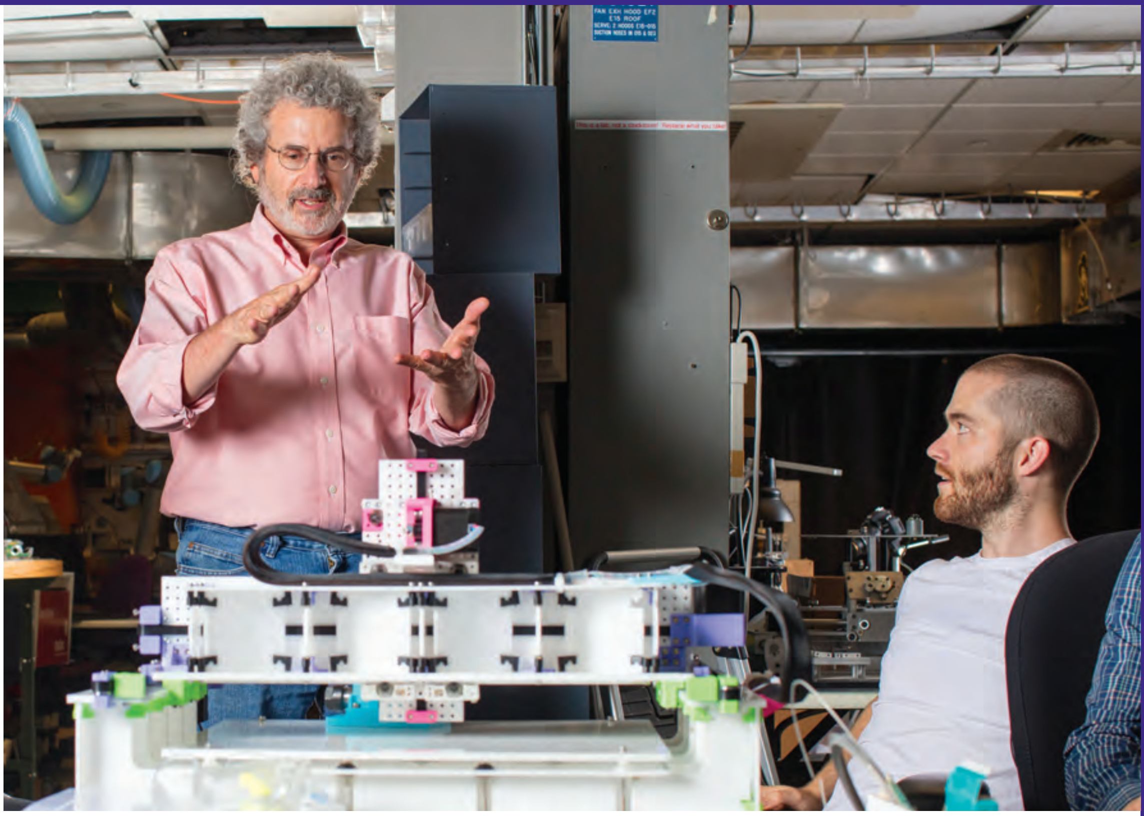
Program in Art, Culture and Technology Mars Lab, **E14-151**

START Studio, **W20-424**

SUTD International Design Centre, **N52-342A**

Making (Almost) Anything

Neil Gershenfeld outlines the impact of fab labs



Neil Gershenfeld has been called the intellectual father of the maker movement. He's spent more than a decade bringing the means for invention to remote corners of the globe via fab labs—facilities for custom-producing objects through digital fabrication (the umbrella term for computer-controlled manufacturing processes). *Spectrum* asked Gershenfeld, a professor of media arts and sciences and director of MIT's Center for Bits and Atoms, about the growing popularity of fab labs—a topic he explores further in *Designing Reality*, a book he co-authored with his brothers, Alan and Joel.

How did fab labs get started?

NG: I teach the perennially oversubscribed MIT class How to Make (Almost) Anything (MAS.863). This started modestly to train users of the Center for Bits and Atoms' digital fabrication research facility, and subsequently grew to add shop sections through the Department of Architecture, then the Department of Electrical Engineering and Computer Science, and then Harvard. Inspired by what the students were doing in the class, and by the analogy with the history of minicomputers (which came between mainframes and PCs), my colleagues and I developed fab labs as an outreach project for the National Science Foundation. We put together a package of the most-used tools and processes from our shop to take into the field, including 3-D printing, scanning, and design; laser cutting, machining, molding, and casting; and electronics production, assembly, and programming. Fab labs today, like minicomputers a few decades ago, cost about $100,000 and fill a room. That cost is coming down as the equivalent of PCs for fabrication emerge, and also going up as regional super-fab-labs appear.

Where are fab labs located? How are they used?

NG: The first fab lab was started in Boston in 2003 with community pioneer Mel King at the South End Technology Center. The number of fab labs has been doubling ever since, approaching 2,000 now (this scaling has come to be called Lass's Law, after Sherry Lassiter who manages the program). They're located from the top of Europe to the bottom of Africa, and from inner cities to rural villages. They are, of course, used to make things—projects range from furniture to whole houses, from circuit boards to computers, from skateboards to drones, and from kitchen utensils to aquaponic systems. But in many cases, the act of making is itself more important than what's made. Fab labs are used to teach classes, incubate businesses, build community, reduce conflict, and create infrastructure. To support these activities, we've spun off programs including a Fab Foundation for operational capacity, a Fab Academy for distributed hands-on education, and Fab Cities for urban self-sufficiency.

> "Fab labs are used to teach classes, incubate businesses, build community, reduce conflict, and create infrastructure," Gershenfeld says.

What's your vision for the future of fabrication? What are its implications?

NG: Fab labs today can make (almost) anything, but they rely on a global supply chain for their inputs—they can't yet make things like integrated circuits or precision bearings. But that boundary is steadily receding; research in the Center for Bits and Atoms is progressing through a roadmap in four stages. First is making things with machines, then comes rapid prototyping of rapid prototyping so that a fab lab can make a fab lab. After that, we're replacing additive and subtractive processes with assembly and disassembly to create the full range of technologies from a small set of building blocks, as happens in biological systems. And, finally, we're eliminating the distinction between machines and materials by coding the construction of self-reproducing systems. These are all being developed in parallel, but it's not necessary to wait decades for the research to be completed to see its impact. Its current state is similar to the historical moment when the internet emerged; a National Fab Lab Network Act has just been submitted in Congress to charter universal access to digital fabrication. We're finding that thinking globally while fabricating locally offers an alternative to conflict over issues including tariffs, jobs, and inequality.

Neil Gershenfeld, left, works with graduate student Jake Read in the fab lab at MIT's Center for Bits and Atoms.

PHOTO: M. SCOTT BRAUER

Customizing the Physical World

Stefanie Mueller advances personal fabrication for all

Stefanie Mueller refuses to accept that objects in the material world must remain as they are; she prefers to think of physical reality as endlessly customizable. When she casts her eye across a room, she seizes upon all the things that could be transformed and personalized.

Take her office. Opposite the door, next to the window, is a black leather couch that forms an L around a glass table. No matter the occasion for using the couch—a formal meeting with a funding agency or a playful brainstorming session with her research group—the couch remains the same.

But Mueller imagines a couch that can change, starting with its outward appearance. She and her students are working with a collection of "photochromic" inks that go from clear to colorful when activated by specific wavelengths of ultraviolet light. They mix together three transparent dyes (that can become cyan, yellow, or magenta), spray-coat the mixture onto a surface (like a couch), and then use the ultraviolet light to change the object's color. The color endures until the object is hit with a different specific wavelength in the visible spectrum. That resets the dyes to transparent, which means "you can infinitely erase and recolor as you like," says Mueller.

Across the lab, two research students are conducting a demo of the technique. They have loaded a psychedelic pattern into the computer and are projecting it onto the door of a small model car. Within minutes, the door recolors. Mueller's team has already applied the technology successfully to mobile phone cases, and she's eager to try it with clothing and actual cars.

The X-Window Consortium Career Development assistant professor in the Department of Electrical Engineering and Computer Science with a joint appointment in the Department of Mechanical Engineering, Mueller heads up the HCI Engineering Group at the Computer Science and Artificial Intelligence Lab at MIT, where she works at the intersection of human-computer interaction and personal fabrication.

Her mission is "to enable the physical world to behave like the digital world." Online and on our phones, we can edit videos, apply photo filters, and personalize our virtual lives with the flick of a finger. Mueller is seeking ways to reprogram and customize the physical world so we can make similar edits to our very reality.

She says that the maker movement, which has embraced increasingly affordable technologies like 3-D printers and laser cutters, is allowing us to knit together our physical and digital worlds. But obstacles remain. Making something on a laser cutter, for instance, requires a high level of technical expertise, including knowing how to tweak dozens of settings to get the object you want when the cuts are complete.

To address this gap between interest and aptitude, Mueller is analyzing the workflow to find ways of automating those intermediate steps. Which is to say that to achieve her goal of building a future where anyone can create anything anywhere anytime, Mueller is developing both the hardware and software to advance personal fabrication for all. It's in part what motivates her teaching, which centers on getting students to dream up and then build their own ways of bending reality (like adjustable-height high heels or a fishing rod that doubles as an interactive gaming device).

Recoloring is just the beginning for Mueller. She muses about reshaping objects: "How great would it be if you could take your mobile phone and just pull on the corners and the screen and everything would get bigger?" she ponders. Mueller is also trying to flex function in the physical world, finding ways of imbuing objects with multiple forms and purposes at once.

Mueller says she takes nothing in the world for granted. Everything is mutable. Reality is rubbery. And being unsatisfied with the way things are is the only mechanism "to live this dream of making everything dynamically changeable." —Ari Daniel PhD '08

Left: Stefanie Mueller watches Rafael Olivera-Cintron '22 demonstrate the interactive gaming device he built to "catch" fish on his laptop.

PHOTO: GRETCHEN ERTL

Above: Using photochromic inks and different wavelengths of light, Mueller and her team can change the appearance of this model car.

PHOTOS: COURTESY OF STEFANIE MUELLER

Sensor Boosts Cancer Fight

MIT-engineered tech to guide radiation therapy

Cancer patients undergoing targeted radiation therapy may soon benefit from technology developed at MIT to address tumor hypoxia, the diminished supply of oxygen to malignant tissue, which can pose a serious barrier to effective treatment.

Higher radiation exposure is required to kill cancerous cells in oxygen-depleted portions of a tumor, but physicians haven't yet had a practical way of measuring oxygen levels within diseased tissue. However, MIT researchers in the laboratory of Michael Cima, the David H. Koch Professor of Engineering, are now readying a suite of implantable oxygen sensors to perform this vital task.

Gregory Ekchian MEng '10, PhD '18, one of Cima's postdoctoral fellows, is responsible for bringing this technology out of the laboratory through research partially funded by a Lemelson-Vest grant and a Kavanaugh Translational Innovation Fellowship—both of which support the transfer of ideas from academia into the world beyond.

"I came to MIT interested in entrepreneurship, knowing it was a critical part of the process to bring new and impactful technologies into clinical use," Ekchian says. Under Cima's supervision, he earned a PhD from MIT for his role in developing the oxygen sensors, and the two have since founded a company, Stratagen Bio, built around this technology.

Gregory Ekchian works with oxygen-sensitive silicone in his lab at MIT.

PHOTO: KEN RICHARDSON

The first clinical implementation incorporates oxygen-sensitive silicone into the tip of the kind of catheter commonly used in brachytherapy, a treatment strategy involving the temporary placement of radioactive seeds in tumors. The modified catheter, which has small holes to allow for interaction with the tumor environment, contains proprietary medical-grade silicone—a substance that absorbs oxygen from its surroundings.

Once the sensor is embedded within a tumor, Cima explains, "you can determine the oxygen content of that tissue by seeing how much oxygen the silicone absorbs." Molecular oxygen, he adds, is "paramagnetic," meaning that the amount of oxygen in the silicone can be assessed through routine magnetic resonance imaging scans. After placing silicone-based sensors in the tumor, doctors can see how oxygen levels vary and calibrate radiation dose levels as needed throughout the course of treatment.

Ekchian sought clinical partners for human trials and found willing collaborators at Boston's Brigham and Women's Hospital. "People have been hoping for something like this for years," notes Robert Cormack, a radiation oncology physicist at the Brigham and associate professor of radiation oncology at Harvard Medical School. "We've had other procedures for characterizing hypoxia but nothing that was clinically viable until this idea came along."

The first clinical applications of the oxygen sensors, according to Larissa Lee—the director of gynecologic radiation oncology at the Dana-Farber/Brigham and Women's Cancer Center and an assistant professor of radiation oncology at Harvard Medical School—will most likely be for cervical and prostate cancer patients. A large number of people could benefit from this approach; about 13,000 new cases of cervical cancer and 175,000 new cases of prostate cancer are diagnosed in the United States every year. Lee is overseeing the first clinical trial, which started this year with 10 patients who are undergoing brachytherapy for cervical cancer.

If the researchers show they can successfully measure tumor oxygen levels during the trial, a follow-up study will evaluate the use of that information to steer radiation to oxygen-deprived regions. Ekchian and other lab members are already preparing for the next round of studies. These efforts focus on enhancing the performance of the oxygen-sensing brachytherapy catheter and on deploying the silicone sensors in diverse settings that don't involve catheters. The hope is that the sensors will ultimately prove useful in a broad range of medical applications.

This prospect is exactly what drew Ekchian to the Cima lab in the first place. "The approach here is not to make things incrementally better," he explains. "Instead we're focused on meeting pressing medical needs that have not been addressed before." –Steve Nadis

Steve Nadis is a 1997–98 MIT Knight Science Journalism Fellow.

Fabrication Goes Global

Grad students run maker workshops in Kenya

As undergraduates at the University of Nairobi in Kenya, Juliet Wanyiri and Marian Muthui realized their good fortune. The engineering students enjoyed hands-on learning opportunities at fabrication laboratories on campus, which were outfitted with essentials such as 3-D printers and milling machines.

This wasn't the case elsewhere in Kenya. For many budding Kenyan engineers, concepts like artificial intelligence and human-centered design are merely theoretical. When the two women became graduate students at MIT, this gulf appeared even wider.

"Lots of undergraduates who go through the university system in Kenya don't get to build until their final year. It's a gap," Muthui says, noting that MIT provides an environment of creative learning and problem-solving—including hands-on engineering—at every level. "We found a dearth of that in Kenya."

To fill this gap, the pair founded Mekatilili (formerly Foondi Workshops) in 2016. The educational initiative, named after a historic Kenyan heroine, runs maker workshops for African students, giving them the design and engineering skills to succeed in the job market.

Wanyiri is a Jacobs Foundation and MasterCard Fellow in the Legatum Center for Development and Entrepreneurship and graduate student pursuing MIT degrees in both Integrated Design & Management and the Department of Mechanical Engineering; Muthui is a graduate researcher at the MIT Media Lab in the Lifelong Kindergarten group. Mekatilili is supported by the Legatum Center and the Media Lab, along with the Technological Innovations for Inclusive Learning and Teaching Lab at Northwestern University.

Muthui

Wanyiri

The roots of Mekatilili can be traced back to the University of Nairobi, where the two women pursued fieldwork funded by the MIT D-Lab, which develops practical approaches to addressing global poverty. Wanyiri focused on improving water sanitation in Brazil, while Muthui worked with Ugandans in remote encampments where people couldn't safely travel at night. Using a makerspace created by D-Lab, Muthui collaborated with residents to develop—and market—miniature lights. These experiences spurred the women to co-create Mekatilili.

"I was so inspired. I wondered, 'How can I create access to what I learned and help young people?'" Muthui says.

Before coming to MIT, Muthui was a biomedical engineer at GE, and Wanyiri was an operations systems support engineer at Nokia Networks. They used those professional connections to launch Mekatilili as a series of ad-hoc maker workshops in Kenya. "We were trying to help people become critical problem-solvers using design and electronics," Muthui says.

With MIT's support, the pair has since expanded the initiative, recently launching the Mekatilili Fellowship Program, a three-day workshop for undergraduates and young professionals in Kenya that includes a mentoring component. The inaugural program, held in January 2019, received more than 300 applications for 30 openings.

"The aim of the fellowship is to create an avenue in which we mentor students," Wanyiri says. "A project-based fellowship is impactful for preparing young professionals with critical problem-solving skills for the job market."

The program matched students with Kenyan companies across three sectors. "Design for accessibility" fellows worked with the Association for the Physically Disabled of Kenya, using artificial intelligence to develop a preventive maintenance schedule for wheelchairs. "Design for manufacturing" fellows collaborated with AB3D, a 3-D printing and hardware company, on sustainable printing solutions. "Design for agriculture" fellows worked with Twiga Foods, a mobile-based, business-to-business food supply platform, on smart technologies.

Fellows also attended professional development sessions led by the Media Lab. "Companies want people with past experience working on practical challenges," says Muthui. "Participants have told us that, when they went back to their schools, the fellowship helped them not only with school-related work but also to look for employment."

The program was so successful that the pair aim to expand the model to other countries in 2020. They hope that their work will improve students' educational experiences—and Africa's economy.

"Our larger vision for Mekatilili is to play a role on the continent in successfully reinventing manufacturing processes, creating new jobs, and revitalizing markets and regions by developing innovative new products and technologies that transform our daily lives," Wanyiri says. —Kara Baskin

Above: Two women work on developing a smart weather monitoring system during a Mekatilili workshop in Kenya.

PHOTOS: COURTESY OF MEKATILILI

Setting the Scene

Student designers learn about architecture, engineering—and themselves

Working on the production of a play called *The Chalk Cycle* at MIT's W97 theater last fall, Daniel Landez '21 had an idea. The play, written and directed by Claire Conceison, the Quanta Professor of Chinese Culture and Professor of Theater Arts, was a three-part show about two mothers—one adoptive, one biological—fighting over a child. The last act dealt with the real-life custody case of Anna Mae He, a Chinese girl born in the United States in 1999. Initially, set designer Sara Brown planned to use a backdrop of legal documents to illustrate the case. Landez, working as a student assistant on the production, suggested they use photographs of Anne Mae and her parents instead.

"We wanted to really solidify with the audience that the story being told by the actors was about real people, which doesn't always happen in theater," Landez says. He made a mockup of three panels with photos interlaced with text. Brown loved the idea and worked with Landez to turn the panels into collages that would float behind the actors as they performed—offering a moving counterpoint to the drama on stage.

Landez is one of many students involved in creating the sets, costumes, and lighting that make theater productions at MIT come alive. These elements provide a rich environment for the actors but are performances in themselves as well. Their making also teaches students a language of expression that's as enriching as their coursework in science, math, and engineering.

"A lot of architects think of set design as mini-architecture," says Landez, who is majoring in the subject. "But the two practices are quite different in the way they approach the built environment." The focus in theater on what an audience sees—in contrast to the more immersive elements of building design—has made Landez more conscious of how buildings appear from different vantage points and enabled him to exercise his creativity. "Coming from the architecture realm, where everything needs to be safe and buildable, it's great to come into a space where I can try and create my own reality."

Architecture student Daniel Landez '21 works on a set design in W97, the new Theater Arts Building.
PHOTO: M. SCOTT BRAUER

Making it real

Brown, an assistant professor of theater at MIT, encourages students to use their creativity in making theater set designs both for classes and productions. Because theater is such a dynamic environment, students must apply their skills so that sets will function and last through an entire production run. "Students have to create a machine to run seamlessly on all dimensions of space and time. If everything isn't where it's supposed to be, the whole piece can fall apart," she says.

That's what Margaret Kosten '20 found so thrilling about working as stage manager for the production *World of Wires* at W97 in the spring of 2018. Written and directed by Class of 1949 Professor Jay Scheib, the play, based on a television series by Rainer Werner Fassbinder, is a madcap evocation of characters living inside a hyper-intelligent computer simulation of the world.

"There were pyrotechnics on stage, fake blood everywhere, random props being thrown, and people crawling over things," says Kosten, a mechanical engineering major, who is considering a double major in theater. "It was insane." The centerpiece of the production was a huge wall constructed from dozens of white cardboard boxes, upon which a video was projected. Halfway through the show, the wall exploded into pieces, littering the stage with boxes in a moment that had to be perfectly timed for maximum effect.

"Stage management and engineering are pretty similar—you have to be very organized and think through problems before they happen," says Kosten. "But there's something about the length of a show and the human variability that makes it a much different kind of temporality than thinking about the turnover of an engine or the filling of a plastic mold."

Her favorite part is calling out the cues that ensure the production runs flawlessly. "You have to call it when it feels right. It's not going to be the same every night."

Challenging students

Scheib originally conceived of *World of Wires* eight years ago in workshops with Brown and students in which they experimented with many different types of materials and sizes before settling on 18-by-18-inch cubes. In May 2019, he taught an advanced studio course called Live Cinema Performance, in which he challenged students to design their own short pieces out of a series of prompts—a tornado, a failed fist fight, an embarrassingly long embrace. Students wrote scripts and developed a video framework with which to shoot the performances, which were broadcast live to an audience this past spring.

"Using audio and visual technology allows artists to use multiple tropes of storytelling simultaneously," Scheib says. In creating the pieces, he encouraged students to think beyond the 4-by-8-foot flats used for traditional theatrical scenery. "Students used rocks and sand and buckets of fake blood," Scheib says. "I think they learned to see a broader range of potentiality in objects we have on hand."

Designing for the theater teaches students to work with multiple elements to make a theatrical vision a reality. In high school, Sam Seaman '21 started out acting but quickly realized that she preferred working behind the scenes. Since coming to MIT, she has designed lighting for productions of *Spamalot* and *You're a Good Man, Charlie Brown*.

Her favorite shows to design for, however, are dance performances such as those for the Asian Dance Team, which requires lighting changes to be made on the fly. "There's no better feeling than the satisfaction you get when you're doing a bunch of stuff behind the board and making the lights go crazy for a big wind-up in the music, and then you time something like a strobe hit or a rotating pattern hit exactly in line with the drop," she says. "It's definitely one of the most fun things as a light designer."

Working on lighting design, Seaman says, has given her a better eye for color and lighting angles—and even changed the direction of her studies. While she initially planned to double-major in physics and math, designing for theater made her realize she wanted to create more tangible products. Now she is an architecture major, and she's also taking classes in mechanical and aerospace engineering. "Lighting design was the start of my realizing that I'm not a scientist, I'm an engineer."

Creating for the theater can also have a profound emotional impact on students' development. In a course on set design with Brown, Landez was given an assignment to create a set for *The America Play* by Suzan-Lori Parks about a black Abraham Lincoln impersonator who is assassinated.

"It's a really devastating play for me, being of mixed race," says Landez, who is half-white and half-Hispanic. "It made me think a lot about how I perceived my brownness growing up."

As a child, he says, he always thought of his brown skin as "dirty." In designing his set, he intentionally set out to create the opposite impression. "I designed the entire set in steel, marble, and granite," he says. "I really liked the idea of creating a monument for a man of color that was clean and polished." Even though he only created the set on computer, it remains one of Landez's favorite projects—affecting him as much as a designer as it would any audience. "It helped me think about who I am," he says, "and how I fit into the puzzle that is MIT."

—Michael Blanding

"Lighting design was the start of my realizing that I'm not a scientist, I'm an engineer."

Sam Seaman '21

Top: Rionna Flynn '21 can be seen behind the wall of boxes that was a central element of the set for *World of Wires*.

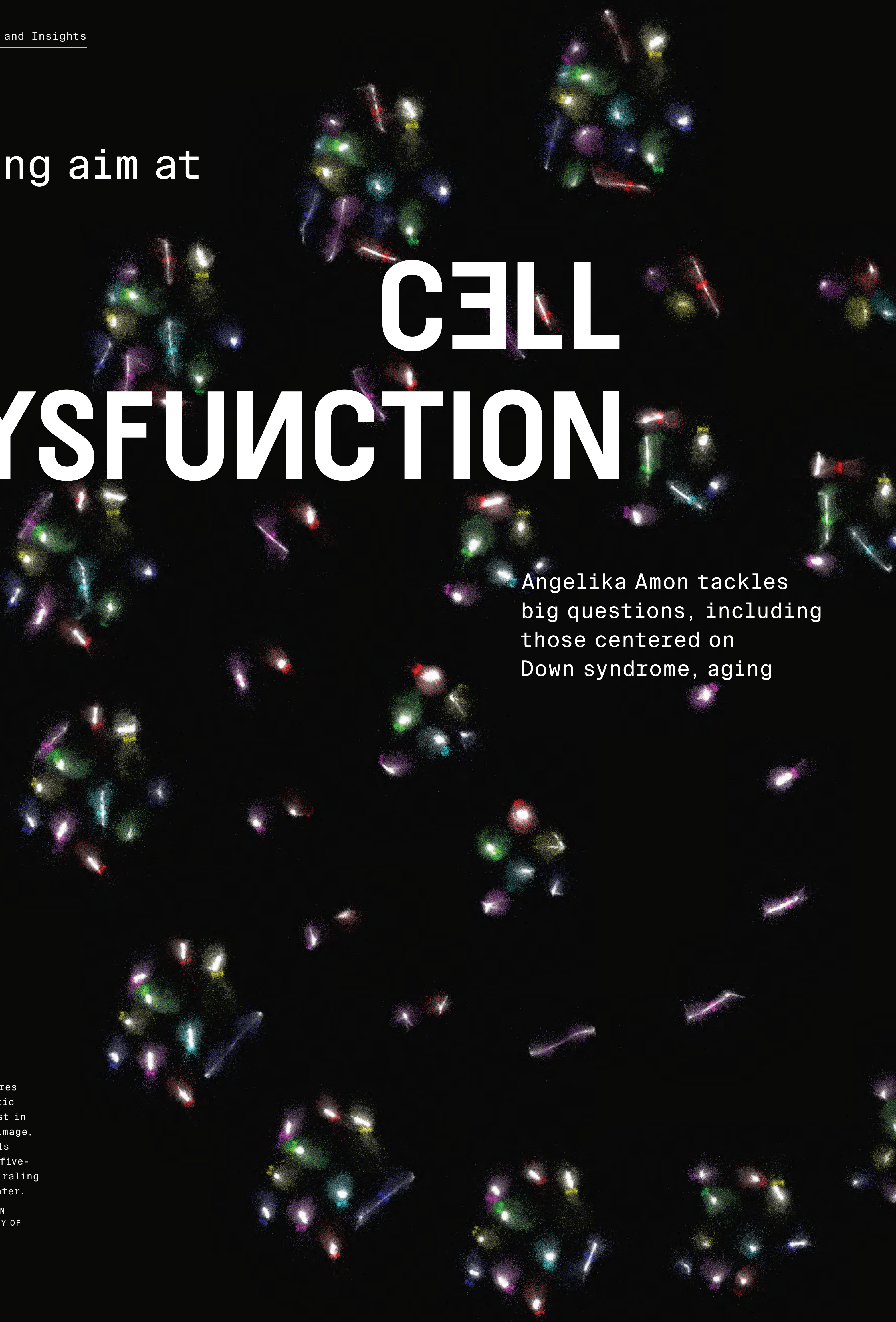
PHOTO: SARA BROWN

Left: Photos of the real people involved in a custody case form the backdrop for MIT's 2018 production of *The Chalk Cycle*.

PHOTO: DANIEL K. LANDEZ

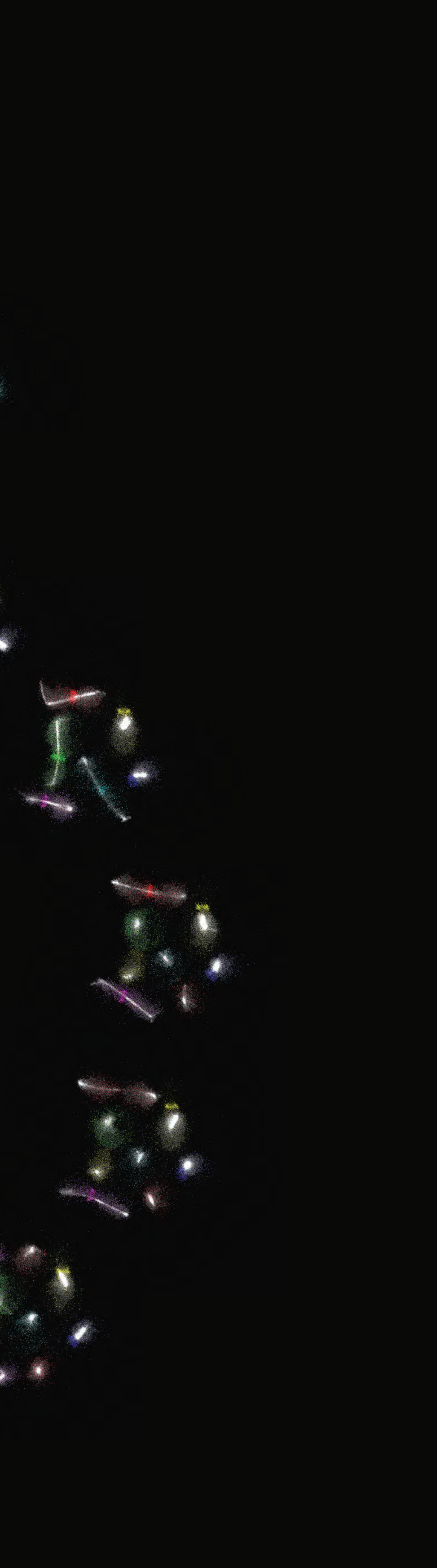
Taking aim at CELL DYSFUNCTION

Angelika Amon tackles big questions, including those centered on Down syndrome, aging



Protein structures divide the genetic material of yeast in this composite image, which shows cells dividing over a five-hour period, spiraling out from the center.

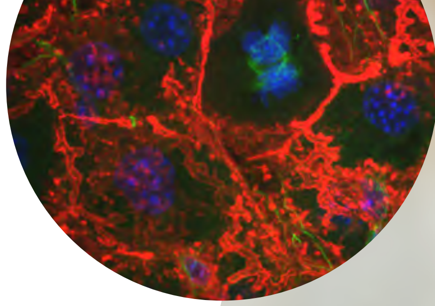
PHOTO: IAN WINSTEN CAMPBELL, COURTESY OF KOCH INSTITUTE



Angelika Amon is annoyed about aging. Not because it happens—that's unavoidable—but because we still can't describe what aging even *is*. "I hate this imprecise language of cells in the body getting 'worn out.' Everybody says this, but what does it mean?" she asks. "You are 'worn out' if you run a marathon. But comparing cells to a human person is just completely unhelpful. It's just improvised language that means gobbledygook."

"I have to say," she adds, "a lot of times I start working on something because I'm annoyed that it makes no sense."

Other things annoy Amon for the same reason. Cancer. Down syndrome. Her research on these conditions has earned Amon a succession of eminent titles—she is the associate director of the Paul F. Glenn Center for Biology of Aging Research at MIT (which was founded in 2015 with a $2 million grant from the Glenn Foundation for Medical Research), codirector of the Alana Down Syndrome Center, and the Kathleen and Curtis Marble Professor in Cancer Research in the MIT Department of Biology. But, the Vienna-born biologist insists she is just trying to answer "simple questions" about how cells work.



Amon

"I call it the 'grandma principle,'" Amon says. "Something is worth studying if you can explain it in a simple way to your relatives who aren't scientists—for instance, your grandma—and then she goes 'Ooh, that's interesting.'"

Amon's grandma-friendly questions are all about chromosomes, the tightly wound coils of DNA that reside within the nucleus of every animal and plant cell. All healthy human cells (except sperm and eggs) contain 46 chromosomes; Amon investigates what happens to cells when that number deviates from the norm, a condition called aneuploidy. For example, Down syndrome is caused by an extra copy of the 21st chromosome, and 90% of solid tumors are made of aneuploid cells.

"Having extra chromosomes is pretty bad," Amon says. "The reason is because when you change the number of copies of an entire chromosome, you change the expression of all the genes that are on that chromosome. That really affects the composition of the cell and causes stress in all its internal processes," including protein folding and metabolism.

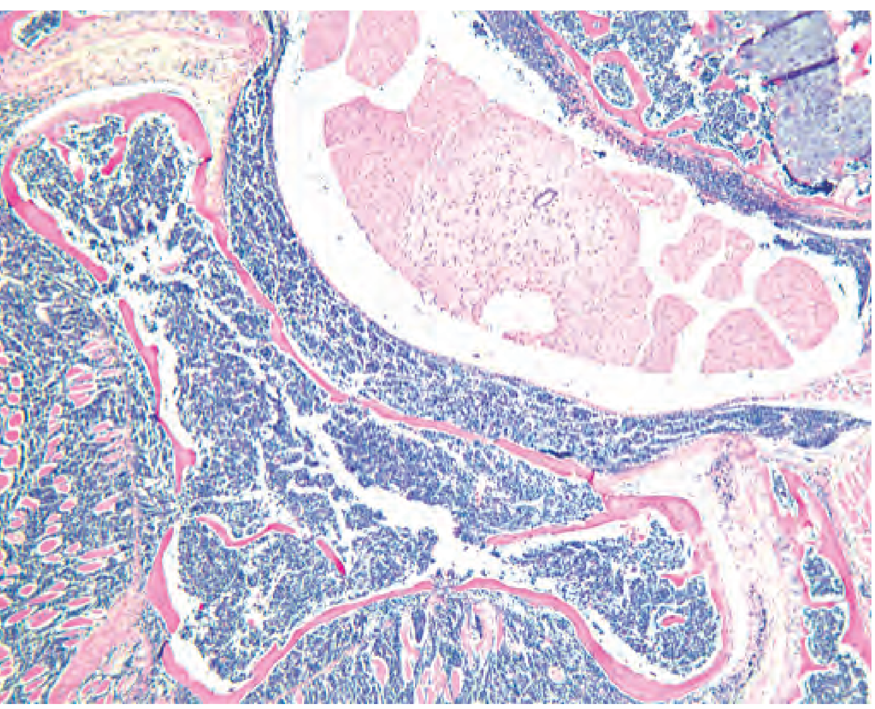
Down syndrome

Amon hypothesizes that this cascade of negative effects within cells is responsible for some of the health problems associated with Down syndrome, such as acute lymphoblastic leukemia, which is 20 times more prevalent in children with the disorder. "Everybody looks for the one specific gene on chromosome 21 where having an extra copy causes all these problems in Down syndrome," Amon says. "But if the generic stresses caused by aneuploidy also contribute to some of the traits observed in Down syndrome, we can begin to think about targeting these general effects to improve some of the difficulties that individuals with Down syndrome experience."

Amon finds the connection between aneuploidy and tumor cells, which divide uncontrollably, similarly intriguing. "We have a paradox here," Amon says. "Aneuploidy makes cells really sick, so why on earth would it also be a key characteristic of a disease—cancer—that's defined by unrestricted cell proliferation?" Amon suspects that aneuploidy must confer some genetic advantage on tumor cells that outweighs the negative effects of having an entire extra chromosome. "The condition must bring something to the cancer, otherwise it wouldn't persist," she explains.

For example, while aneuploidy causes a tumor cell's genome to become unstable—"Bad!" as Amon says tersely—this instability also lets the cell "roll the dice more often" to generate potentially useful genetic alterations, such as the ability to metastasize to other tissues or resist chemotherapy. Amon and her collaborators are investigating whether aneuploid tumor cells have the same weaknesses seen in noncancerous aneuploid cells; if so, she says, the next step would be to develop a drug targeting this "vulnerability of the aneuploid state."

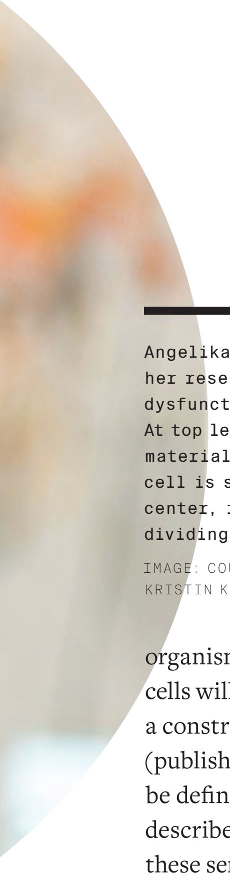
"If we had a drug that miraculously only killed aneuploidy cells, it would be incredible," Amon says. Such a drug wouldn't be appropriate for people with Down syndrome or other chromosomal disorders, because every cell in their bodies is aneuploid. But for people without these disorders, "it would work on basically all solid tumors, but at the same time it wouldn't touch normal cells," she explains, noting that



Angelika Amon sees parallels between aneuploidy (cells with an abnormal number of chromosomes) and cancer (cells that divide uncontrollably). This image shows leukemia cells (stained blue) in mice.

IMAGE: COURTESY OF PEI-HSIN HSU

"By studying very fundamental questions in biology, you actually end up learning important things about human health," Amon says.



Angelika Amon focuses her research on the dysfunction of cells. At top left, the genetic material of a liver cell is shown (at center, in green) dividing abnormally.

IMAGE: COURTESY OF KRISTIN KNOUSE MD, PHD

such a drug remains in the distant future. “We don’t have it yet, but we’re working on it.”

Cellular aging

Amon is also searching for a straightforward mechanism to explain cellular aging, or “cellular senescence”—a phenomenon that scientists believe contributes to the overall aging of organisms. Biologists have known since 1961 that normal human cells will divide only 40 to 60 times before ceasing to replicate—a constraint known as the Hayflick limit. Amon’s latest research (published in *Cell* in February 2019) shows that this limit may be defined by a cell’s physical size. “When Leonard Hayflick first described this senescence phenomenon, he pointed out that these senescent cells were actually huge,” Amon says. She showed that when cells below the Hayflick limit are induced to grow larger than they should be, “they have all the characteristics of senescent cells.”

But why do cells get so large, and why should that increased size cause a cell to senesce and ultimately stop dividing? The explanation, Amon says, lies in how cells repair damage to the DNA coiled in their chromosomes. Natural DNA damage occurs constantly, and cells must periodically pause their natural dividing process (called the cell cycle) to fix it. However, other processes inside the cell—such as building proteins and other biomolecules—*don’t* pause during DNA repair. As a result, every time the cell cycle stops, the cell gets a little larger. If a cell becomes too large, its own genes can’t direct the production of enough protein to sustain the cell’s function—and cellular functions decline and the cell becomes senescent.

One clue supporting this connection between size and senescence, Amon explains, is that doubling the number of genes inside the cell—which doubles the amount of proteins it builds to sustain itself—reverses the aging process. “The cell resurrects when we induce genome doubling in extremely large cells,” Amon says. Furthermore, when Amon uses a drug called rapamycin to inhibit cells’ ability to manufacture proteins (and get larger) while pausing to repair DNA damage, “the cells stay small and stay young—they don’t lose their replicative potential,” she says. “We’ve known for a very long time that DNA damage causes senescence, but nobody could explain it. I think we’ve come up with a proposal for why this is happening—cells get larger during the time they arrest in the cell cycle to repair the damage, and when they are large they lose their functionality—this appears to be universally true from yeast to humans.”

Amon insists that her work on aging and aneuploidy—which earned her a 2019 Breakthrough Prize in Life Science—is less about discovering clinical applications, and more about answering the “grandma questions” that initially excite her curiosity (and occasionally annoy her). “I’m a concept person,” she says. “I’m very interested in how it all works together in the big picture. By studying very fundamental questions in biology, you actually end up learning important things about human health. But at heart, I am just a very basic scientist who studies cells.” —John Pavlus

Alana Gift Launches Down Syndrome Center

As part of its continued mission to help build a better world, MIT is establishing the Alana Down Syndrome Center, an innovative new research endeavor, fellowship program, and technology development initiative for inclusion launched with a $28.6 million gift from the Alana Foundation, a nonprofit organization started by Ana Lucia Villela of São Paulo, Brazil.

Based out of MIT’s Picower Institute for Learning and Memory, the center will engage the expertise of scientists and engineers in a multidisciplinary research effort to increase understanding of the biology and neuroscience of Down syndrome. The center will also provide new training and educational opportunities for early career scientists and students to become involved in Down syndrome research.

The center will be co-directed by Angelika Amon, the Kathleen and Curtis Marble Professor in Cancer Research, and Li-Huei Tsai, director of the Picower Institute and the Picower Professor of Neuroscience.

The Alana gift will also fund a four-year program with the MIT Deshpande Center for Technological Innovation that will encourage creative minds around the Institute to develop technologies that can improve life for people with different intellectual abilities or other challenges. Together, the center and technology program will work to accelerate the generation, development, and clinical testing of novel interventions and technologies to improve the quality of life for people with Down syndrome.

“At MIT, we value frontier research, particularly when it is aimed at making a better world,” says MIT President L. Rafael Reif. “The Alana Foundation’s inspiring gift will position MIT’s researchers to investigate new pathways to enhance and extend the lives of those with Down syndrome. We are grateful to the foundation’s leadership—President Ana Lucia Villela and Co-President Marcos Nisti—for entrusting our community with this critical challenge.”

With a $1.7 million gift to MIT in 2015, Alana funded studies to create new laboratory models of Down syndrome and to improve understanding of the mechanisms of the disorder and potential therapies. In creating the new center, MIT and Alana Foundation officials say they are building on that partnership.

“We couldn’t be happier and more hopeful as to the size of the impact this center can generate,” Villela says. “It’s an innovative approach that doesn’t focus on the disability, but instead focuses on the barriers that can prevent people with Down syndrome from thriving in life.”

Nisti adds, “This grant represents all the trust we have in MIT, especially because the values our family holds are so aligned with MIT’s own values and its mission.” Villela and Nisti have two daughters, one with Down syndrome.

Adapted from a March 20, 2019, article by David Orenstein of the Picower Institute for Learning and Memory and published by MIT News.

Chemistry for a Cure

Ronald Raines applies fundamental science to target disease

Ronald Raines '80 was first drawn to chemistry and biology as an undergraduate at MIT, where he completed a double major, studying enzymes in a chemistry lab on the first floor of the Dreyfus Building.

Some three decades later, he is back in that same building, gesturing excitedly at protein models arrayed in his office along with books and travel mementos. As he discusses his research, the "Brass Rat" class ring on his hand provides a tangible reminder of where he began. And, it's clear he is just as interested in chemistry and biology as he ever was.

Raines, who joined the MIT faculty in 2017 after a long career at the University of Wisconsin–Madison, serves as the Firmenich Professor of Chemistry at MIT—a professorship with a distinguished 40-year history. He leads a lab pursuing projects at the interface of two fields that are poised to have a major impact on medicine and society.

"I've always liked tangibility, I've liked science I could touch, and chemistry and biology are both sciences that I can touch," Raines explains. "I love projects that span from very fundamental science all the way to a clinical outcome—that's the goal."

One such project that has occupied Raines's lab for the past five years started with a straightforward concept: Proteins are complex molecules that carry out many key tasks in cells, but mutations in the DNA blueprint used to build them may result in dysfunctional proteins—and when these damaged proteins are involved in how cells grow or divide, it can lead to cancer. So, Raines thought, what if you could overcome such cancer-causing mutations by simply replacing dysfunctional proteins with working versions?

Unfortunately, there's a snag. Proteins are large and have negative charges, which makes it basically impossible for them to pass through a cell's protective membrane—a dense, negatively charged lipid bilayer. "[This layer] is very difficult to cross—it has evolved to keep the outside out and the inside in," Raines explains. "There are very, very few proteins that can naturally enter human cells, and even those do so inefficiently."

What was needed, Raines realized, was a way to smuggle proteins across this protective membrane undetected.

Enter what Raines has dubbed "ghost proteins." Adapting a process used in medicinal chemistry to move drugs into cells, Raines and his lab have developed a technique that creates an invisibility cloak for proteins. The basic idea is that a protein undergoes a chemical reaction that turns its negatively charged, acidic carboxyl groups into neutral ester groups, thus allowing it to sneak into a cell. Once inside, the cell's enzymes convert these ester groups back into carboxyl groups, removing the protein's invisibility cloak and restoring its function.

"We're very excited about this; we've demonstrated this with a handful of proteins, and we are seeking to expand this to many, many proteins, including ones that can be used in new therapies," Raines says.

Developing new cures is the biggest and most interesting research challenge, the "gold ring on the merry-go-round," Raines says, but he views the therapeutic potential of these ghost proteins more broadly—as an untapped territory brimming with possibilities.

Raines's lab, which consists of almost two dozen postdoctoral researchers, graduate students, and undergraduates, is also working on myriad other projects at the intersection of chemistry and biology, including creating artificial collagens to treat wounds, developing cancer drugs from enzymes called ribonucleases, and establishing a process for fabricating biofuels.

"An advantage of having a group that's broad in its interest…is that people talk to each other about ideas that are seemingly far afield at the outset, but can often be merged to create a whole that is bigger than the sum of the parts," Raines says.

Being at MIT is also an advantage, he adds. "It's so exciting. It's so vibrant. It's on the cutting edge in every field that interests me."

–Catherine Caruso SM '16

PHOTO: BRYCE VICKMARK

To Fuel the Future, a Look Back

An excerpt from *Jump-Starting America*

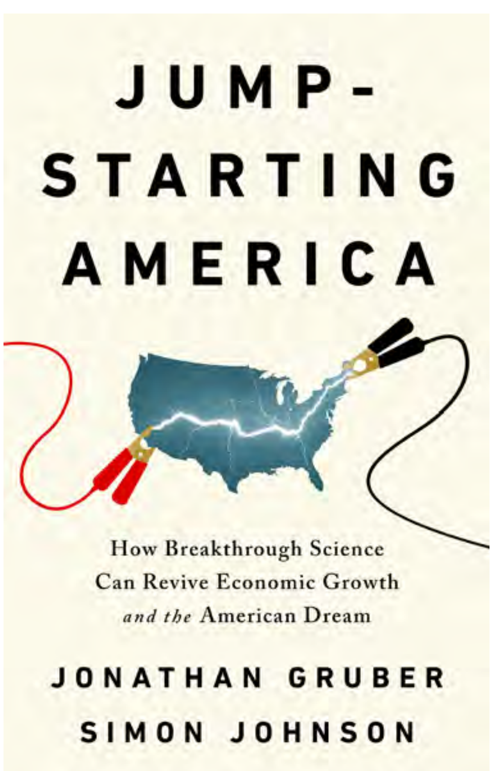
Gruber

Johnson

Boosting economic growth in the United States requires an ambitious new plan for increasing public investment in science and technology, akin to the push for research and development that propelled the nation's post-WWII expansion. That's the premise of *Jump-Starting America: How Breakthrough Science Can Revive Economic Growth and the American Dream* (PublicAffairs, 2019), a new book by Jonathan Gruber '87, professor of economics at the MIT School of Humanities, Arts, and Social Sciences, and Simon Johnson PhD '89, the Ronald A. Kurtz Professor of Entrepreneurship at the MIT Sloan School of Management. In this excerpt from the chapter, "The Postwar Invention Boom," the authors remind us of the role science, engineering, and MIT have played in America's success story.

> "The wartime science effort propelled a generation forward in terms of scientific and industrial achievement."

Vannevar Bush [PhD 1916, former professor and dean of the MIT School of Engineering] was a master of managing perceptions. He understood firsthand that "engineers" of the day were regarded by senior military personnel as "in all probability a thinly disguised salesman, and hence to be kept at arm's length"—and he insisted that his team be referred to consistently as scientists. In one sense, this was accurate, as the people he hired, particularly for the Rad Lab [the MIT Radiation Laboratory, which researched radar], were actually scientists, mostly physicists.



Realistically, however, most of their wartime efforts were devoted to applications that should more accurately be regarded as engineering—applications of existing knowledge to practical problems—rather than as science, the creation of new knowledge through theory and controlled experiments. Still, their strong training in science served these "engineers" well once they could take their wartime experiences, including with hands-on electronics, back to their labs—and onto inventions such as digital computers and semiconductors.

The postwar invention boom was boosted by the fact that the devices and processes developed under the NDRC [National Defense Research Committee] (and its successor, the higher-profile and better-funded Office of Scientific Research and Development [OSRD]) were to some extent rough and ready—everyone was in a hurry to make things work and deploy robust versions into combat situations. The flip side was that many interesting problems became more obvious, both in terms of basic science and potential further improvements for products....

As a direct continuation of the government-supported wartime aerospace program, it was the Americans who brought the next generation of jet engine–based flight technologies to scale. It was America, not exhausted and cash-strapped Britain or broken Germany, which proved best positioned to take advantage of the related commercial developments....

Of all the wartime science projects, radar can undoubtedly claim the longest list of useful spin-off products. Modern commercial air travel is made possible by hundreds of radar systems across the United States. Much of the useful information in weather reports is based on some form of radar.

Astronomy was transformed by the creation of radio telescopes. Particle accelerators and microwave spectroscopy can also trace their lineage back to the MIT campus—as can the nuclear magnetic resonator (the basis for modern magnetic resonance imaging, MRI) and the maser (used in atomic clocks and spacecraft, and forerunner of the laser), for which work Nobel Prizes were awarded in 1952 and 1964, respectively....

Old Washington hands like to emphasize that "personnel is policy"—meaning that who you hire has a major impact on what gets done. But conversely, who gets trained to do what, while working for the government, can have significant impact on what they think about—and invent—later. Judged in those terms, the wartime science effort propelled a generation forward in terms of scientific and industrial achievement. Ten Nobel Prizes can either be traced back to work done at the Rad Lab or were won by people who spent formative years building radar systems.

Most of the postwar top science advisors to government cut their teeth somewhere in the OSRD, most commonly at the Rad Lab. Right through to the Nixon administration, thinking about science policy—and what exactly to support—was shaped by people who had worked alongside Vannevar Bush.

IMAGES: COURTESY OF PUBLICAFFAIRS

THOMAS PHD ’04 AND LILY BEISCHER

Inspired by Architecture Faculty

For more than four decades, the History, Theory, and Criticism of Architecture and Art (HTC) program at the MIT School of Architecture and Planning has been on the forefront of exploring the larger questions and challenges within architectural history. Thomas Beischer, who earned a PhD from the HTC program in 2004, wants to keep it that way.

Tom teaches architectural history and theory at Stanford University, and his spouse, Lily Beischer, is a stock analyst and portfolio manager. Together the pair recently made a significant gift to support HTC faculty, establishing the Beischer Family Faculty Research Fund to ensure the HTC remains on the leading edge of contemporary architectural history scholarship.

“It’s the faculty, with their leadership, vision, and mentorship that really puts the HTC ahead,” says Tom. “These funds will help them do their research in the best possible way.”

Tom credits the HTC faculty, particularly his dissertation advisor, Mark Jarzombek PhD ’86, professor of the history and theory of architecture, with broadening the vision of MIT’s architectural history program to embrace a global view of the field, rather than a Western-centric one. Jarzombek is the author of the seminal textbook *A Global History of Architecture* (Wiley Press, 2006) and was instrumental in starting the new Global Architectural History Teaching Collaborative, a group of architectural scholars from around the world who are creating teaching materials for non-Western subjects in college-level architectural history survey courses.

To determine how their gift could be used best, Tom engaged in a series of conversations with Jarzombek, with whom he remains close, as well as other members of the HTC faculty. For Tom, the gift’s ultimate direction was simply a matter of having confidence in the faculty. “As much as I would trust them to help me do my dissertation, I trust them in knowing the needs of the department the best,” he says.

Tom, who completed a master’s degree in art history at Williams College, came to MIT searching for a doctorate program with a “density of activity”—something he found not only in the HTC, but also in the wider Institute and Cambridge communities. He discovered that the program had an “incredibly strong alumni network” that helped make MIT a hub for architectural historians from around the world to share research and ideas.

Tom says his experience at MIT also helped him understand the deeper layers of connection between architectural theory and practice and expanded his interests beyond physical buildings. “Now, in my teaching at Stanford, I make sure that the undergraduates I work with begin to understand how buildings, practice, and theory are intertwined,” he says. “I didn’t fully understand that dynamic before I got to MIT.”

The Beischer Family Faculty Research Fund follows a recent gift that the Beischers made to the HTC to support travel. That fund enabled 23 graduate students to go on a 2018 HTC trip to Sri Lanka. Travel is crucial for understanding architecture, says Tom, who believes a large part of thinking about architecture globally is being on site and seeing buildings in context, “alive and at work.”

The Beischers’ gifts to MIT are part of the couple’s efforts to make educational opportunities more equitable. Both Lily and Tom support schools they’ve attended, and Tom serves on the national board for the Breakthrough Collaborative, which offers educational programs for high-achieving, underserved middle and high school students.

When reflecting on the timing of the gift, the Beischers say that it was important for them to make it while they are still “relatively young” and can see their gift bear fruit. “It’s a joy for us to know that the faculty is going to feel supported,” says Lily. Adds Tom, “The reason I have such a great passion for MIT and am still passionate about architectural history and theory is because of the faculty. That’s what inspires us to support MIT.” —Katy Downey

PHOTO: DAVID ROBERT ELLIOTT

CLAIRE AND RALPH ’70 BRINDIS

A Partnership of Interests and Opportunity

Claire and Ralph ’70 Brindis have devoted their lives to improving human health through evidence-based medicine and public policy. Their recent gift to establish the Brindis Family Fund at MIT’s Institute for Medical Engineering and Science (IMES) extends that commitment and advances groundbreaking work by MIT faculty and students at the intersection of science, engineering, and translational medicine.

“We’re scientists and scholars,” says Claire, “so we’re very interested in the role of evidence” in improving human health and well-being. It’s a priority they see reflected in the cross-disciplinary work of IMES and across MIT.

The Brindises are pleased that their fund will support graduate fellows working with Elazer Edelman MD, director of IMES and Edward J. Poitras Professor in Medical Engineering and Science. Edelman also serves on the faculty of Harvard Medical School and is senior attending physician at Brigham and Women’s Hospital. Ralph describes Edelman as a “visionary” who is generating “incredible innovations in the treatment of cardiovascular disease” through pioneering research in vascular biology and the development and assessment of biotechnology for cardiac care.

The Brindis family’s MIT connections run deep: Ralph’s father and uncle were MIT graduates, and he completed his undergraduate degree in biology at MIT in 1970. He moved to Los Angeles to earn a master’s of public health (MPH) degree at the University of California, Los Angeles (UCLA), where he met Claire, who was also pursuing an MPH at UCLA. As they pursued successful careers in medicine and public health and raised two sons, Ralph and Claire have remained one another’s greatest champions: “We are each other’s best agents in terms of pride in each other’s careers and accomplishments,” says Claire.

Today, Ralph is a leading cardiologist and professor at the University of California, San Francisco (UCSF), who has devoted his career to advocating for quality care for cardiac patients. His distinguished career has encompassed creating national cardiovascular clinical practice guidelines, data standards, performance measures, and appropriate use criteria. Ralph is best known as the father of the National Cardiovascular Data Registry, which collects data on the safety and efficacy of implanted cardiac devices and cardiac treatment. His professional honors include serving as president of the American College of Cardiology and in numerous leadership roles in health care and policy making.

Claire, who immigrated to the United States from Argentina as a child, is a professor and director of UCSF’s Philip R. Lee Institute for Health Policy Studies. She is widely recognized for her scholarship in children’s and women’s health policy, health equity, and social determinants of health. She served on the National Academy of Medicine’s (NAM) committee on women’s preventive health services and is proud that the committee’s recommendations helped to shape the Affordable Care Act, benefiting millions of American women (Claire was elected to NAM in 2011). Claire has recently co-authored a book, *Advocacy and Policy Change Evaluation: Theory and Practice* (Stanford University Press, 2017), and is expanding her efforts to help community-based organizations strengthen their work through advocacy.

“We’re scientists and scholars,” says Claire, “so we’re very interested in the role of evidence.”

Ralph describes the Brindis Family Fund as “the perfect marriage” of the couple’s interests and the mission of IMES. Claire adds that by supporting graduate students at IMES, they are also supporting Edelman’s “very authentic commitment to mentoring,” a practice that has been important in their own careers.

As they look to the next phase of their lives, Ralph and Claire remain actively engaged in their fields while making more time for personal projects and family. Their sons, daughters-in-law, and four grandchildren are a particular source of joy.

Ralph looks forward to his 50th Reunion in 2020 to celebrate his MIT experience and to honor his father, who died of heart disease shortly before his own 50th MIT Reunion. These intersecting links to MIT and loved ones remain important to their family, says Ralph, and the chance to be part of MIT’s future through the Brindis Family Fund is “an incredible privilege.” —Kris Willcox

PHOTO: DAVID ROBERT ELLIOTT

A Harmonious New Addition

Building will give music a major lift

Below: MIT's flute ensemble, The Institooters, performs during the Independent Activities Period.

PHOTO: SARAH BASTILLE

MIT has made a historic commitment to expand and enhance music education at the Institute with the construction of a dedicated music building. The Institute is entering the final fundraising stage for the transformative structure, which will be designed by Tokyo-based architectural firm SANAA and will be adjacent to Kresge Auditorium.

The building's central location on campus reflects the important role that music studies and performance have at MIT. For decades, Institute leaders have recognized the arts as an irreplaceable component of an MIT education. The new music facility is the latest manifestation of that commitment, building on a renewed visibility for the arts heralded by the opening of the new theater and performing arts building in 2017.

Keeril Makan, the Michael and Sonja Koerner Music Composition Professor and section head of MIT Music and Theater Arts, says he is confident that the new building will enrich the music community. "For the majority of MIT students, the Institute's combination of a world-class science, engineering, and humanities education with superb music training is one key to their creativity, success, and well-being," he says. "Just as the theater arts building has rapidly transformed that discipline on campus, MIT's new music building will be an active laboratory for what our music faculty have called the 'synergies that arise from the confluence of great technical minds and extraordinary musical talent.'"

In fall 2018, a gift from Joyce Linde, a longtime supporter of MIT and the arts, launched the music building into the architectural planning phase. Two important leadership gifts from Brit d'Arbeloff '61 and Ray SM '78 and Meredith Rothrock were made in the same year. These supporters join a group of earlier donors, who for many years have been dedicated to seeing this building project come to fruition.

"There is a tremendous community of music lovers at MIT who have made the music building possible,"

The Rambax Senegalese Drum Ensemble, led by Director Lamine Touré, performs at the Isabella Stewart Gardner Museum in Boston.

PHOTO: DANNY GOLDFIELD

In a typical year, more than 1,500 undergraduates enroll in MIT music classes—consistently making Music and Theater Arts one of the top-five highest-enrolled departments.

says Melissa Nobles, Kenan Sahin Dean of the MIT School of Humanities, Arts, and Social Sciences.

"Through their generosity, we will have a center that better serves MIT faculty and students, as well as the Greater Boston community. We look forward to securing the final commitments needed to begin construction."

The building, which is currently scheduled to open in late 2022, will provide immediate benefits to participants in MIT's innovative music program as well as to the wider performance-going community. In a typical year, more than 1,500 undergraduates enroll in MIT music classes—consistently making Music and Theater Arts one of the top-five highest-enrolled departments—and music is among the most popular of the Institute's 42 minors. Beyond the classroom, more than 500 musicians participate in one of 30 MIT ensembles, chamber groups, or advanced music programs every term.

"The building will be a true place of 'mind and hand,'" says Makan, "where our students and faculty can experiment at the frontiers of music and share their discoveries with our community and the larger world."

—Joelle Carson

Better World Events Highlight Vision and Talent of MIT

The MIT Campaign for a Better World is all about meeting urgent global challenges through the vision and talent of the MIT community. Mark your calendar to hear about the latest groundbreaking work from Institute leaders, faculty, students, and alumni at these upcoming events.

INNOVATION AND ENTREPRENEURSHIP

Westchester/ Fairfield

Thursday, February 27, 2020
Crowne Plaza Stamford

SCIENCE MATTERS

Toronto

Wednesday, April 29, 2020
Sheraton Centre Toronto Hotel

TOWARD A SUSTAINABLE FUTURE

Minneapolis

Fall 2020
Location to be announced

THE MIT CAMPAIGN FOR A BETTER WORLD

Mexico City

Fall 2020
Location to be announced

(↗)

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MIT Better World events held in the Bay Area in February 2019 featured a photo booth for attendees (inset) and a discussion between Vice President for Open Learning Sanjay E. Sarma, left, and Jenna Hong '19. Sarma, who is the Fred Fort Flowers and Daniel Fort Flowers Professor of Mechanical Engineering, talked about the science of teaching and learning with Hong, who was conducting computing and cognitive science research.

PHOTO: JOSH REISS AT NORRIS PHOTO

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Eswar Anandapadmanaban '20 tests the augmented reality headset he made in the Building 9 makerspace used by VR/AR@MIT, a student organization for hacking computing technologies. He created the headset by adapting an open-source headset prototype design known as Project North Star. "The space of VR/AR is very new, and everyone is experimenting," says Anandapadmanaban, a graduate student in electrical engineering and computer science. "It's kind of the Wild West of designing and building stuff from scratch."

PHOTO: SARAH BASTILLE

MIT CAMPAIGN FOR A BETTER WORLD