

Spectrum

global
health





A scanning electron microscope image shows the Covid-19 virus, SARS-CoV-2, in yellow. This spring, as the pandemic caused by this virus spread, MIT researchers went to work to fight it.

IMAGE: NIAID-RML

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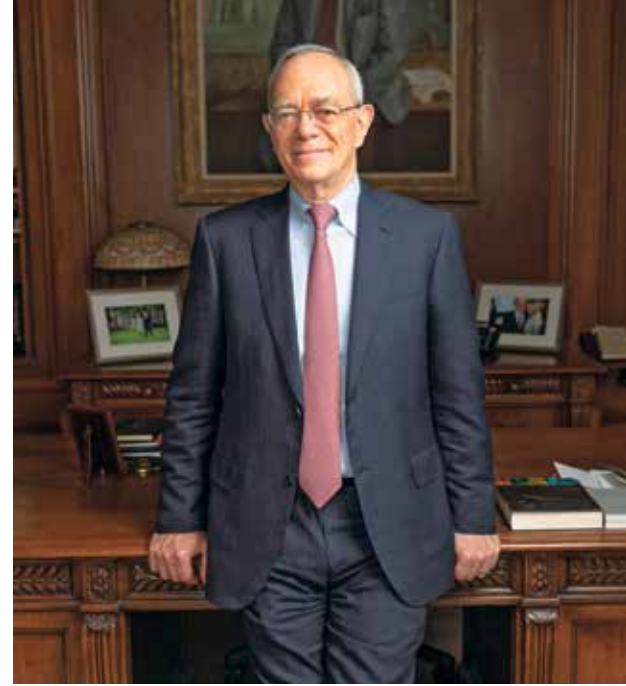
Spectrum Online

Stephanie Eich

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



Strength Built Through Research



The Covid-19 pandemic is teaching us every day what it means to confront a truly global problem. From the sudden reordering of daily life to the most tragic personal consequences, few of us have been left unaffected. For any institution, a challenge of this magnitude naturally has serious practical implications; the arrival of Covid-19 drastically changed campus life overnight and forced us to reinvent nearly every aspect of our operations.

Yet despite this strain, without breaking stride, the people of MIT also began to make immediate scientific and technical contributions to fighting the pandemic. Two factors made this possible: the signature problem-solving drive of our faculty, staff, and students, and the fact that MIT had been laying the groundwork to fight a pandemic—and other urgent global challenges—through our longstanding commitment to fundamental research.

In science and engineering, MIT researchers were already grappling with deep questions bearing on human health: How do we develop effective treatments to fight pathogens? Could new data science methods help us understand the spread of infectious disease? What can atmospheric chemistry reveal about how hazardous substances in the atmosphere affect human health, and how should this inform decision making on climate policy?

At the same time, social scientists had been probing how work conditions influence employees' health, while urban planners were investigating how the neighborhoods we live in shape our personal health outcomes. The answers they found often cast a harsh light on longstanding inequities, making it painfully clear, as we have all seen through the Covid-19 crisis, that socioeconomic disparities play a major role in determining the health of individuals and communities.

In effect, in the face of a pandemic, decades of wide-ranging fundamental research provided a springboard for practical action. As stewards and champions of this research, MIT has the opportunity—and the responsibility—to launch bold, innovative responses not only to the current Covid-19 crisis but to an array of global problems in human health, from the persistent threat of malaria to the impacts of climate change.

With its focus on global health (starting on page six), this issue of *Spectrum* offers a glimpse of some of MIT's extraordinary minds at work. And it makes clear that our common humanity demands that we respond to global health crises with global collaboration.

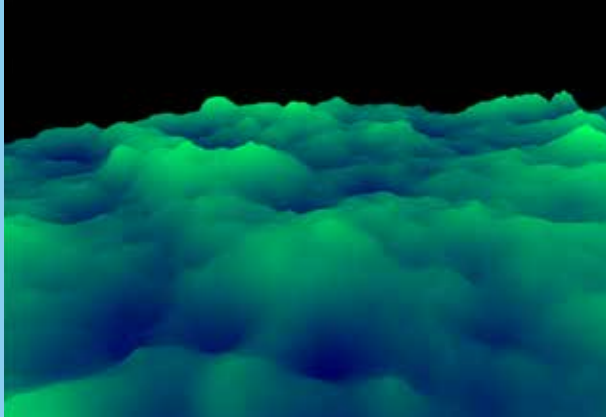
Sincerely,

L. RAFAEL REIF



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betterworld.mit.edu



Algorithms for Art

Class takes deep dive into the making of computer graphics

Solomon: “Computer graphics is all about simulating the real world on a piece of silicon.”

TITLE

6.837 Introduction to Computer Graphics

INSTRUCTOR

Justin Solomon

Associate Professor, Department of Electrical Engineering and Computer Science
Principal Investigator, Computer Science and Artificial Intelligence Lab (CSAIL)

Solomon: “We follow the path of visual content as it moves through your computer, all the way from describing a set of shapes to the actual pixels on your computer screen.”

FROM THE CATALOG

Introduction to computer graphics algorithms, software, and hardware. **Topics include** ray tracing, the graphics pipeline, transformations, texture mapping, shadows, sampling, global illumination, splines, animation, and color.

THE CLASS

A vast invisible world of algorithms powers the artful computer-generated images we see on screens from televisions to smartphones. 6.837 Introduction to Computer Graphics walks students through behind-the-scenes aspects of digitally created visual content.

Helen Ho '19, SM '20, who took the class as an undergraduate and later served as a teaching assistant: “It was really exciting for me to build on all the concepts that I'd learned in the more fundamental computer science classes and visually see the things that I could create.”

“Computer graphics is a densely mathematical and technical discipline,” says associate professor Justin Solomon, who heads CSAIL’s Geometric Data Processing Group. “We really don’t cover the artistic graphic design aspects in this course. It’s more on the mechanics of how a computer generates **visual content**.”

The class follows the computer graphics pipeline, breaking it into focused topics:

TOPIC 1: Whether the end product will be a forest of animated trees or a graphical depiction of complex data, the first step in any computer graphics project is to determine exactly what should be shown on the screen. Students learn how computers represent such things as curves, surfaces, and deformations, as well as how to capture the position and lens of a virtual camera (transformations).

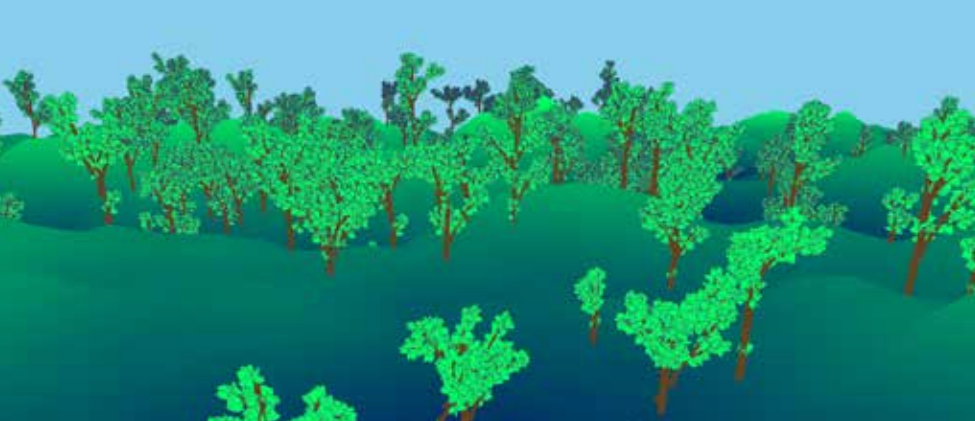
TOPIC 2: The next step is to capture how stationary graphics can change over time—in other words, to animate. Lectures include both computer algorithms and the tried-and-true animation techniques used for the Walt Disney Classics of the early 20th century.

TOPIC 3: Students study two different rendering techniques, the computer processes used to transform data into visual content: **ray tracing** (high quality but long processing time) and **rasterization** (real-time rendering used to avoid lag time in interactive graphics such as video games).

TOPIC 4: At the end of the semester, the class addresses the different types of hardware used in each of the rendering techniques. Students discuss how advancements in graphics processing hardware, for example, have enabled the speedy processing necessary for artificial intelligence and machine learning.

Ray tracing algorithmically simulates the path of light rays as they encounter objects; it gives visual realism to computer-animated films.

With rasterization, visual content can be generated and displayed at speeds of at least 29.97 frames per second, the speed at which computer screens update visual content to outpace the human visual system.



“This is a discipline where the technology is changing every day in really fundamental ways,” says Solomon. “Everything has become so much more sophisticated. The visual content is absolutely stunning in modern games, movies, and design software. That’s really a byproduct of research in this discipline, advances in the hardware, and efficient computing.”

THE ASSIGNMENTS

The assignments track the lectures, **leading students** through the graphics pipeline.

TOPIC 1: Students create stationary 3-D drawings of visual elements such as curves, textures, and various surfaces.

TOPIC 2: Students control an articulated 3-D character and generate a poseable human figure using algorithms that determine the angles of joints. They output the character for display on screen.

TOPIC 3: Students create a simple cloth simulator, where a sphere is draped in a material that can respond to user interactions.

TOPIC 4: Two separate assignments tackle rendering. First, students use ray tracing to generate high-resolution visual content. Second, they use rasterization to create an interactive 3-D scene with shadows that shift and scenery that changes as characters move around.

The final assignment is an open-ended project that lets the students explore their creativity while **implementing the technical skills** they’ve learned throughout the semester. Formatted as a competition, the project gives the winner a chance to attend the annual SIGGRAPH conference on computer graphics and interactive techniques held by the Association for Computing Machinery.

WHAT COMPUTER GRAPHICS IS (AND ISN'T)

Solomon is careful at the beginning of the class to clarify that while computer graphics is an inherently creative discipline, 6.837 is not an animation or graphic design class. Rather, it dives into the heavy mathematical and technical techniques that lie behind the art.

“We see all this content in movies, all these great computer graphics effects,” says Ho. “But I think prior to coming into this class, a lot of students, including me, don’t know what goes into creating these effects. There is actually a significant amount of math, algorithms, and data structures that contribute to the final visual artistry.”

The skills learned in class can be used outside of animated movies, of course. Career opportunities include video game design, computer-aided design, and additive manufacturing. Students can also apply what they’ve learned to write fast, heavily processor-dependent software, such as that used for genomics research and climate modeling.

“We’re surrounded by computer screens all the time,” says Solomon. “And sure, those screens are interfaces to really complicated computational machinery, but they’re also pieces of technology for generating visual content. This area has exploded in terms of its importance and the impressively cool things that people are doing.”

—Stephanie M. McPherson SM '11

Christopher “Jack” Blazes '22: “We went through each of the major steps of creating an image on the screen. I liked that structure a lot.”

Blazes: “Mine was about procedurally generating trees and making them look realistic with some amount of randomness.”

Ho: “Our project extended on techniques we learned in class. We wanted to make a more flexible outer skin that still moved with the underlying skeleton but was less rigid than what we’d created for our assignment. We animated a running man, for example, and could see his stomach jiggle and things like that.”

Christopher “Jack” Blazes '22 used the skills he learned in 6.837 to computer-generate a variety of trees. Cowboy Lynk '20 created reflective balls and a 3-D graphics test model known as the Stanford bunny.

IMAGES OF TREES: COURTESY OF BLAZES

IMAGES OF BALLS AND BUNNY: COURTESY OF LYNK

Drawing Together for Justice

At MIT, making a better world means more than work done in the lab or lecture hall; it means striving to create lasting impact. This spring, roommates Sarah Acolatse '22 and Emily Han '22 decided they wanted to address racial injustice. “Seeing the news about the deaths of George Floyd and Breonna Taylor, I wanted to do something,” Acolatse says, referring to two Black people whose names became rallying cries of the Black Lives Matter movement after they died in the hands of police this year. “I felt pretty helpless.”

Sharing an interest in digital art, Acolatse and Han decided to found MIT Drawn Together, a collective of artists that creates commissioned works of art in exchange for donations of at least \$25. Drawn Together collects these donations and contributes them to the Black Lives Matter Foundation and other organizations focused on racial justice.

“We realized that a bunch of MIT students are very talented artists, and we decided to start a project that would let them use that talent for good,” Han says. Education on justice issues, she points out, is also a significant part of the mission. “It’s a great way to circulate information and show how donations are used.”

The roommates received an enthusiastic response when they announced the project to their fellow undergraduates via email, and their Instagram feed brought the project’s popularity to the next level. “We thought it would be a super small project, but a lot of people wanted to help,” Acolatse says. By the end of July, the pair had a “club” of more than 20 artists—mostly MIT undergraduates—that regularly meets online to discuss their artwork and give each other feedback and support. Some alumni have also gotten involved by promising matching grants from their employers. “I feel a real sense of community, even though we’re not together on campus,” Acolatse says.

In just two months, Drawn Together artists created more than 100 original pieces, raising more than \$3,500. The founders plan to continue the project indefinitely. “After starting this project, I feel like I have been able to express whatever passion I have to support the people I love and care about,” Acolatse says. “It has made me realize that a lot of people really do care about these important issues, and it’s been heartwarming to see.” —Joelle Carson



Acolatse and Han



100+
artworks
commissioned
June–August

IMAGES (CLOCKWISE FROM TOP LEFT): SARAH ACOLATSE '22; AMBER SHEN '22; XIQING WANG '21; YU MENG ZHANG '23; EMILY HAN '22

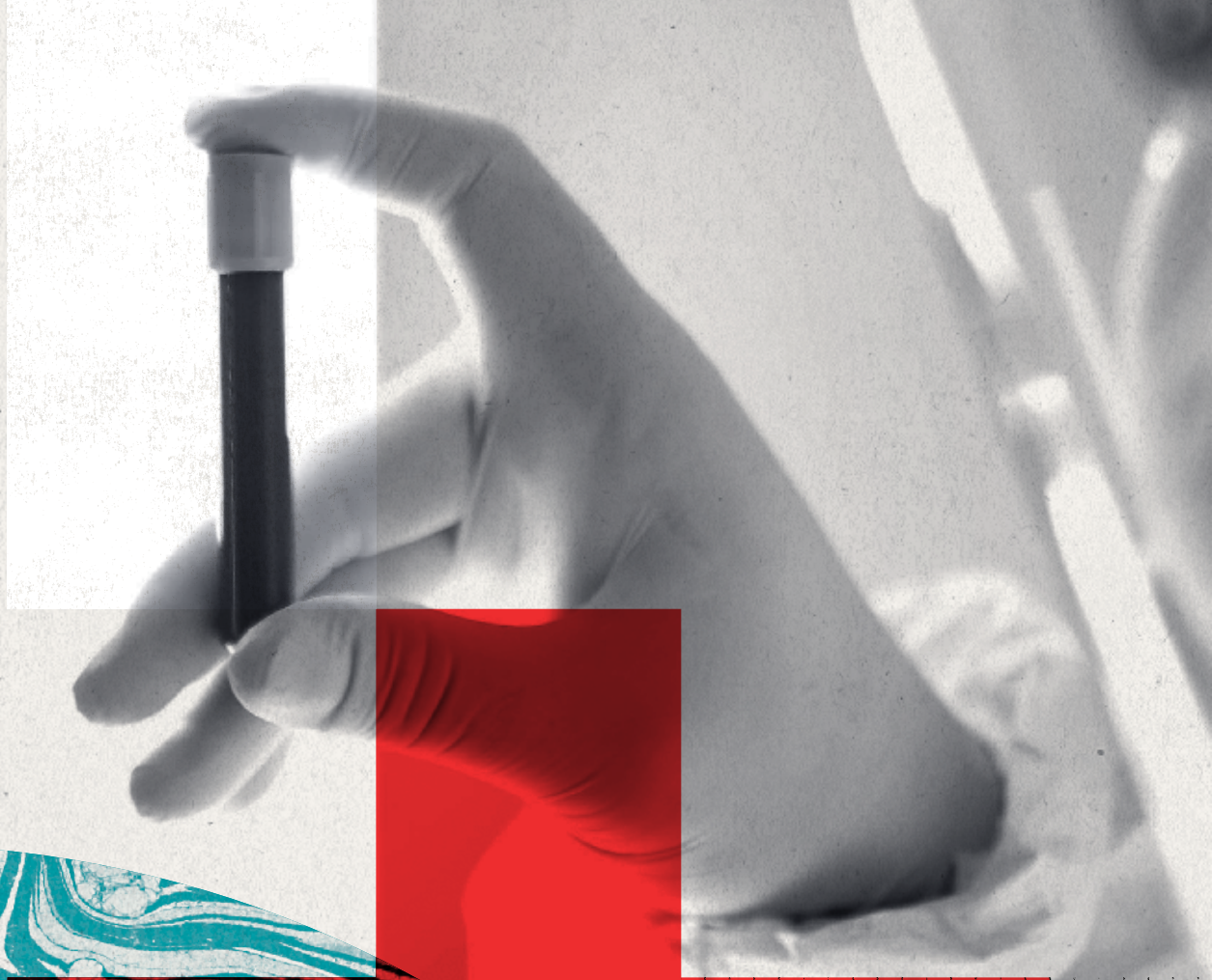
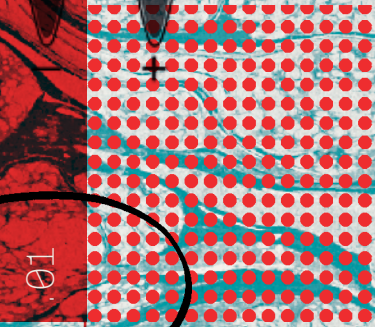
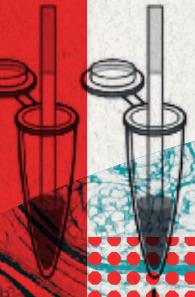


\$3,500+
raised for social
justice organizations
June-August

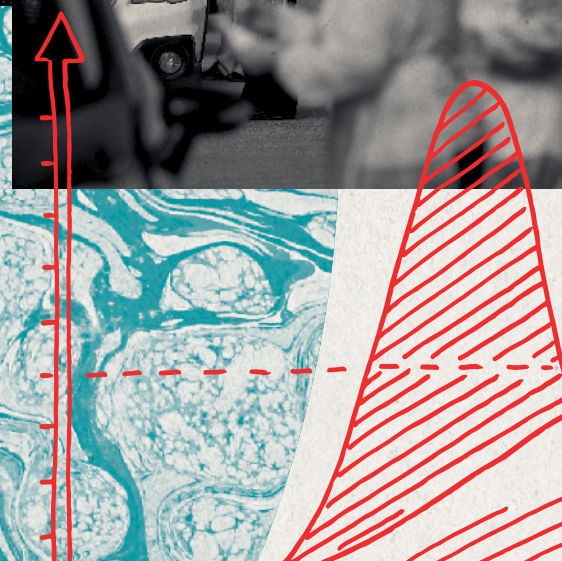
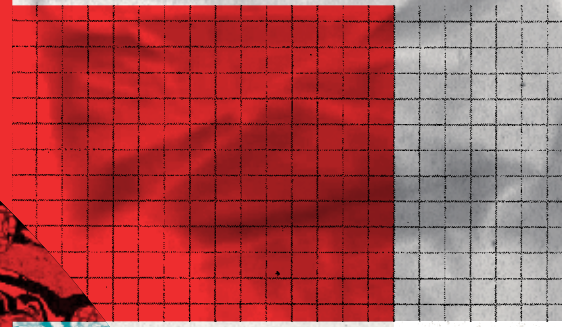



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For more information, visit
[instagram.com/mit.drawn.together](https://www.instagram.com/mit.drawn.together)

01.2020



global health





As Covid-19 began its deadly spread across the globe in 2020, everyone wanted answers. At MIT, the rapid response that emerged relied on tools, techniques, and talents built up over generations. This solid base of cutting-edge work has supported major efforts to combat Covid-19 while also advancing research across the global health spectrum.

Rapid Response

The first cluster of Covid-19 cases was reported to the World Health Organization on December 31, 2019. As the pandemic unfolded, the MIT community quickly rolled up its collective sleeves and went to work—contributing research, donating personal protective equipment, assessing economic impacts, teaching remote classes, and much more. This timeline provides a snapshot* of MIT's extensive efforts to address the crisis during the first few months.



January

A team of researchers at the McGovern Institute for Brain Research at MIT, the Broad Institute of MIT and Harvard, and other departments and centers begin developing tests for Covid-19 using SHERLOCK, a diagnostic tool based on the genome editor CRISPR.

February

The Cambridge-based biotech company Moderna announces it has an experimental vaccine ready to test. Moderna was founded in 2010 by Institute Professor Robert S. Langer ScD '74 (pictured at far left), investor Noubar Afeyan PhD '87, and researchers from Harvard Medical School.

Chemical engineers at MIT's Koch Institute for Integrative Cancer Research dive into work on a Covid-19 vaccine and on ways to ramp up future vaccine manufacturing. (See story on page 16.)

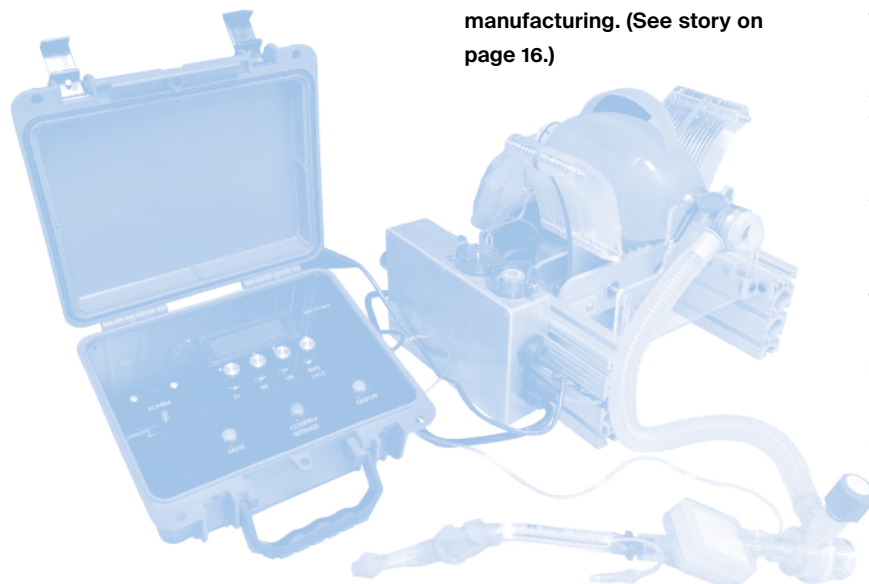
March

MIT Emergency Management establishes the Covid-19 planning team and working groups on March 5.

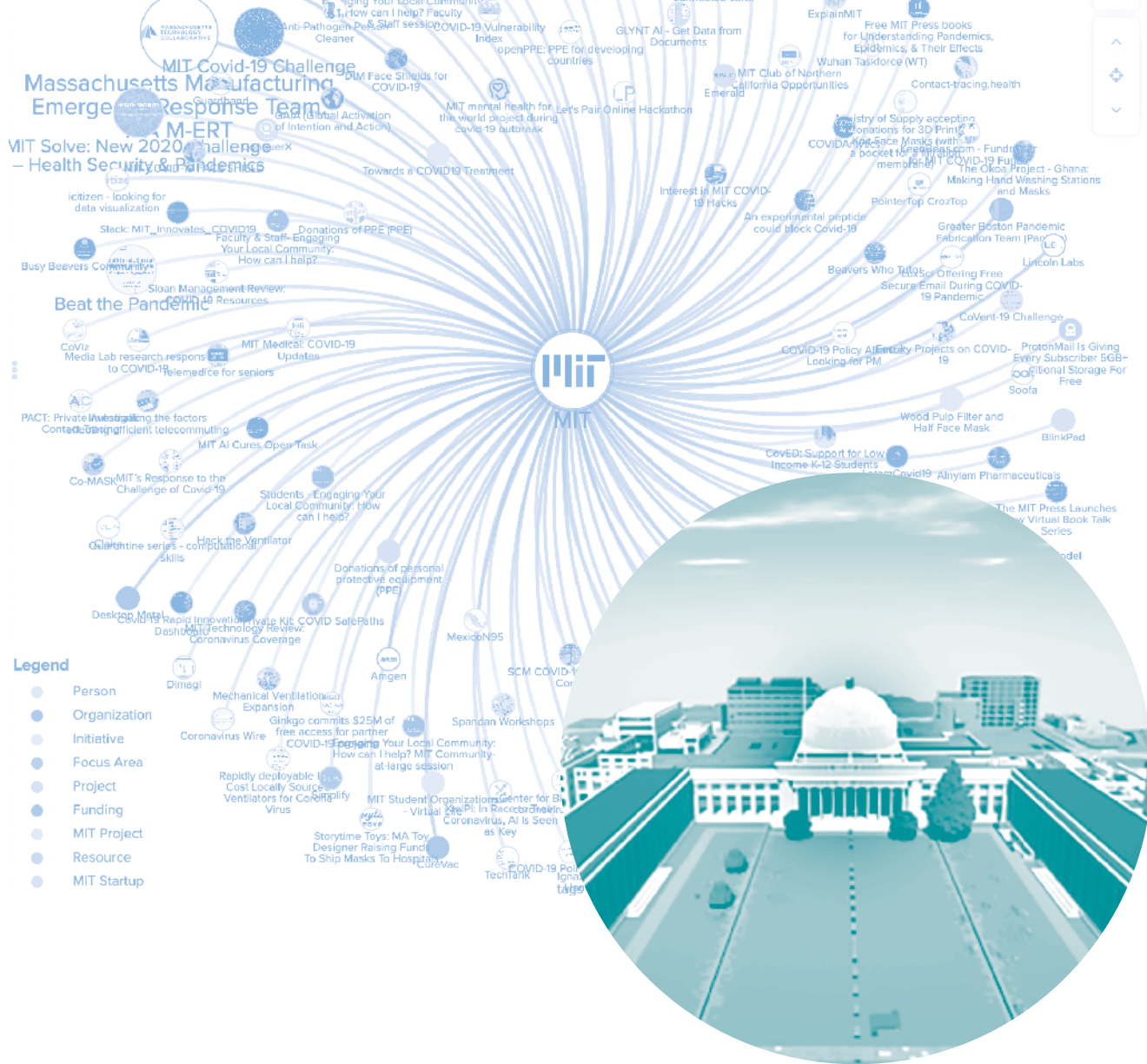
MIT Solve, which uses social impact challenges to tackle the world's biggest problems, launches a \$10,000 global challenge seeking innovations focused on prevention, detection, and response to Covid-19.

On March 10, MIT announces all classes will move online on March 30. Undergraduates are asked to depart campus residences by March 17.

The MIT E-Vent team—including mechanical engineering professor Alex Slocum Sr. '82, SM '83, the Walter M. May and A. Hazel May Professor, his son surgical resident Alexander Slocum Jr. SB '08, SM '10, PhD '13, and MIT research scientist Nevan Hanumara MS '06, PhD '12—forms to work on rapid deployment of an open-source, low-cost ventilator (pictured at left) first introduced in 2010 by a student team in Course 2.75 Medical Device Design.



*This timeline represents work in progress early in 2020. Outcomes of projects vary.



Faculty and staff begin working from home on March 13.

The MIT Abdul Latif Jameel Clinic for Machine Learning in Health forms AI Cures to apply machine-learning methods to finding promising antiviral molecules.

The Stanford-MIT Healthy Elections project launches, bringing academics and election administration experts together to address the unprecedented and ongoing threat that the pandemic poses to the 2020 elections.

Drawing on technology developed at MIT's Institute for Medical Engineering and Science (IMES), startup E25Bio works to develop a quick paper-strip test for Covid-19.

Students from MIT and Harvard University launch CovEducation, a mentoring platform that provides support for children while schools are closed.

MIT students collectively construct a 1:1 scale replica of MIT online in Minecraft (pictured above right).

The MIT Innovation Initiative begins work on the Covid-19 Rapid Innovation Dashboard (pictured above), which will become a hub of MIT's Covid-19-related activities.

A team of MIT chemists reports designing a drug candidate that may block coronaviruses' ability to enter human cells.

Economists, including MIT's Iván Werning, argue that the supply shock of Covid-19 has led to an even larger demand shock, as affected workers lose income and all consumers cut back on spending, and that policy responses are needed to address both types of shocks.

MIT researchers and colleagues propose repurposing a blood clot drug—a protein called tissue plasminogen activator—to aid Covid-19 patients in acute respiratory distress.

The Covid-19 Policy Alliance, a team of MIT faculty and experts, maps the most risk-prone counties in the United States.

More than 50 departments, labs, and centers—as well as individual community members, including alumni and friends around the world—donate personal protective equipment to health care workers. Mail Services and Custodial Services team up to get thousands of items to area hospitals.

Roughly 1,200 MIT subjects move to a remote teaching and learning model. A website developed by the Teaching and Learning Lab, Open Learning, and Information Systems and Technology provides soup-to-nuts instructions on preparing classes for remote delivery.

MIT initiates mass manufacture of disposable face shields (pictured above center; design appears below) for Covid-19 response. MIT's Project Manus, led by mechanical engineering professor Martin Culpepper SM '97, PhD '00, spearheads the project in collaboration with a number of MIT and community partners, including physician Elazer R. Edelman '78, SM '79, PhD '84, director of IMES and the MIT Medical Outreach Team, and the Edward J. Poitras Professor at IMES.

A Slippery Viral Defense

Katharina Ribbeck works to boost protection offered by mucus

Our cells pump out more than a liter of mucus a day: a slimy line of defense against pathogens, toxins, and viruses. Unfortunately, SARS-CoV-2 seems to sneak past mucus with perplexing ease.

Katharina Ribbeck, the Mark Hyman Jr. Career Development Associate Professor of Biological Engineering, wants to pinpoint exactly how SARS-CoV-2, the virus that causes Covid-19, binds to and travels through mucus. “We want to get to the bottom of mucus’s role as an immune barrier,” she says.

Anyone with a cold or allergies is hyperaware of how continuously the body secretes mucus. But mucus, generally scorned as snot, is not just a product of the nose. Part viscous liquid and part elastic solid, mucus hydrates, lubricates, and transports fluids throughout the body. Dedicated cells adjust the amount and type of mucus secreted depending on the threat detected.

This high-magnification image shows mucin polymers, the key component of mucus.

IMAGE: COURTESY OF KATHARINA RIBBECK



Understudied biopolymers

Mucus first captured Ribbeck’s attention when she was studying a different polymer system at the University of Heidelberg. Mucus and its main structural component, biopolymers called mucins, struck her as significantly understudied given their importance in health and disease. Her research to date has drawn attention to the value of mucins, which are now being eyed by the food, agriculture, and biomedical industries for potential use in consumer products.

Bolstering mucus’s role as a security force is its community of microorganisms, or microbiome, which act on toxins and pathogens. Ribbeck and colleagues have identified components within mucus that don’t necessarily kill pathogens but disarm them. Some of these are members of a diverse family of sugars called glycans that protrude from mucin’s bottlebrush-shaped filaments. The exact function of these sugars is still a mystery; Ribbeck calls them “therapeutic libraries” with broad-spectrum effects on microbes, both good and bad.

Within the lungs, these sugars may act as receptors for the signature spike proteins that enable coronaviruses to slip inside a cell and replicate. But sugars in the protective mucosal layer could potentially prevent the virus from entering the cell by mimicking receptors on the cell surface, offering decoy binding sites.

It’s been suggested that influenza A sneaks through mucus by slicing off these decoys. It’s not clear whether SARS-CoV-2 uses this tactic or another means to avoid being trapped in mucus like an insect in tree sap.

An inhaled virus such as SARS-CoV-2 must navigate a relatively thick layer of mucus. Ribbeck says it’s unlikely that viral particles can diffuse through mucus faster than mucus can sweep them out of the body, so SARS-CoV-2 must have evolved a strategy to co-opt or overcome mucus’s defenses. “Something in our understanding of Covid-19 pathogenesis is missing,” she says. Does the virus move through mucus differently than do other particles its size to escape retention? Does it use spike proteins to bind to substances and to propel itself forward, or hitchhike a ride with other microbes?

Exactly how SARS-CoV-2 enters the body is what Ribbeck’s lab has been investigating this year with the help of a National Science Foundation grant. Analyzing samples from healthy and infected patients, both symptomatic and asymptomatic, should help the team understand in more detail how pathogenesis occurs, she says.

Boosting function

Although researchers don’t yet have the tools to precisely tune mucus production within the body, Ribbeck says she and her colleagues are considering ways to engineer, reconstitute, or replenish mucus molecules on body surfaces that have run low or where mucus is not as functional as it should be. There might even be a way to boost the mucus microbiome by supplementing it, the same way that probiotics supplement the gut microbiome.

Repairing or enhancing mucus holds out the hope of a novel approach to foiling viruses such as SARS-CoV-2. “Perhaps it binds to something within mucus in a way that we could potentially disrupt,” Ribbeck says. “Or we could equip the mucus barrier with molecules that trap and clear the virus.” Mucus is already an effective security force; Ribbeck hopes to identify and deliver the extra firepower it needs to overcome a formidable enemy. —Deborah Halber

Unnatural Disasters

Historian links health consequences to human actions

The coronavirus pandemic is not a purely natural disaster. According to Kate Brown, a professor in the MIT Program in Science, Technology, and Society, zoonotic diseases—those initially transmitted from animals to humans, including Covid-19—can occur more frequently and strike more powerfully as a direct consequence of the stresses humans place on the environment.

Contributing to the current pandemic and to other infectious disease flare-ups in recent decades is the fact that animals and humans now live in increasingly close quarters, with human populations encroaching ever further into wildlife zones, Brown maintains. Modern industrial-scale agriculture is another culprit: tens of thousands of chickens, for example, can be raised within a single barn in just six weeks, an accelerated time frame that encourages pathogens to transform from sublethal residents into deadly invaders.

Although self-isolation is a key preventative strategy, the human body is not hermetically sealed, Brown points out. “We’re wading through an atmosphere filled with viruses and bacteria, antibiotic-resistant microbes and radioactive contaminants, and our bodies act like nets in the ocean, catching and filtering almost everything passing through.” Protecting ourselves when we are so porous is a huge challenge, compounded by the fact that we face a vast array of environmental toxins predominantly of anthropogenic origin, in addition to the threats posed by virulent biological agents.

Brown has catalogued many cases where human behavior has compromised the environment, thereby jeopardizing human health and welfare, in a series of award-winning books. The first, *A Biography of No Place: From Ethnic Borderland to Soviet Heartland* (Harvard University Press, 2004), describes a region along the Ukraine-Poland border chronically besieged by war, famine, and ethnic cleansing. She chose the first-person voice for this and her other books, which is unusual for historical works, in order to “bring readers along and help them visualize these places.”

In *Plutopia: Nuclear Families in Atomic Cities and the Great Soviet and American Plutonium*



Professor Kate Brown studies how human behaviors lead to disasters such as the 1986 nuclear explosion in Chernobyl, above, and the 2020 Covid-19 pandemic, left.

PHOTO (ABOVE): FRANCOIS LOCHON / GAMMA-RAPHO VIA GETTY IMAGES

PHOTO (LEFT): DAN KITWOOD / GETTY IMAGES

Disasters (Oxford University Press, 2013), Brown profiled two cities that were built around the world’s first nuclear plants to produce weapons-grade plutonium, one in Hanford, Washington, and the other in Ozersk, Russia. Over a period of decades, each plant unleashed some 350 million curies of radioactivity with devastating repercussions. Similar tales unfold in *Dispatches from Dystopia: Histories of Places Not Yet Forgotten* (University of Chicago Press, 2015), in which Brown explores “modernist wastelands” such as America’s biggest Superfund site, a former copper mine near Butte, Montana, despoiled by arsenic, heavy metals, and contaminated soil, and its counterpart, a ravaged mining town in Kazakhstan. *Manual for Survival* (W. W. Norton & Company, 2019), meanwhile, takes a close look at the medical and environmental consequences of fallout from the 1986 Chernobyl nuclear disaster. Long-lived radionuclides released in that accident are still circulating, with high levels of radiation emitted just this year during forest fires near the reactor complex.

One lesson emerging from Brown’s work is that natural and human-made disasters are now so closely entwined it can be hard to disentangle the two. Yet she sees some grounds for hope, albeit from an unlikely source. “The [coronavirus] pandemic is teaching us a great deal,” she says. “We’ve learned how to slow down, to communicate over the phone and internet rather than getting on a plane every

other day. And people have shown they’re willing to make economic sacrifices to save lives.” Thanks to these changes, CO₂ output has dropped, which means fewer people will die from air pollution and respiratory illnesses, Brown says.

“Economic projections suggest it won’t be easy to get back to where we were,” she adds. “Part of the reset, which I hope is now underway, should involve thinking about more sustainable, just, and equitable ways of resuming our economic activity.”

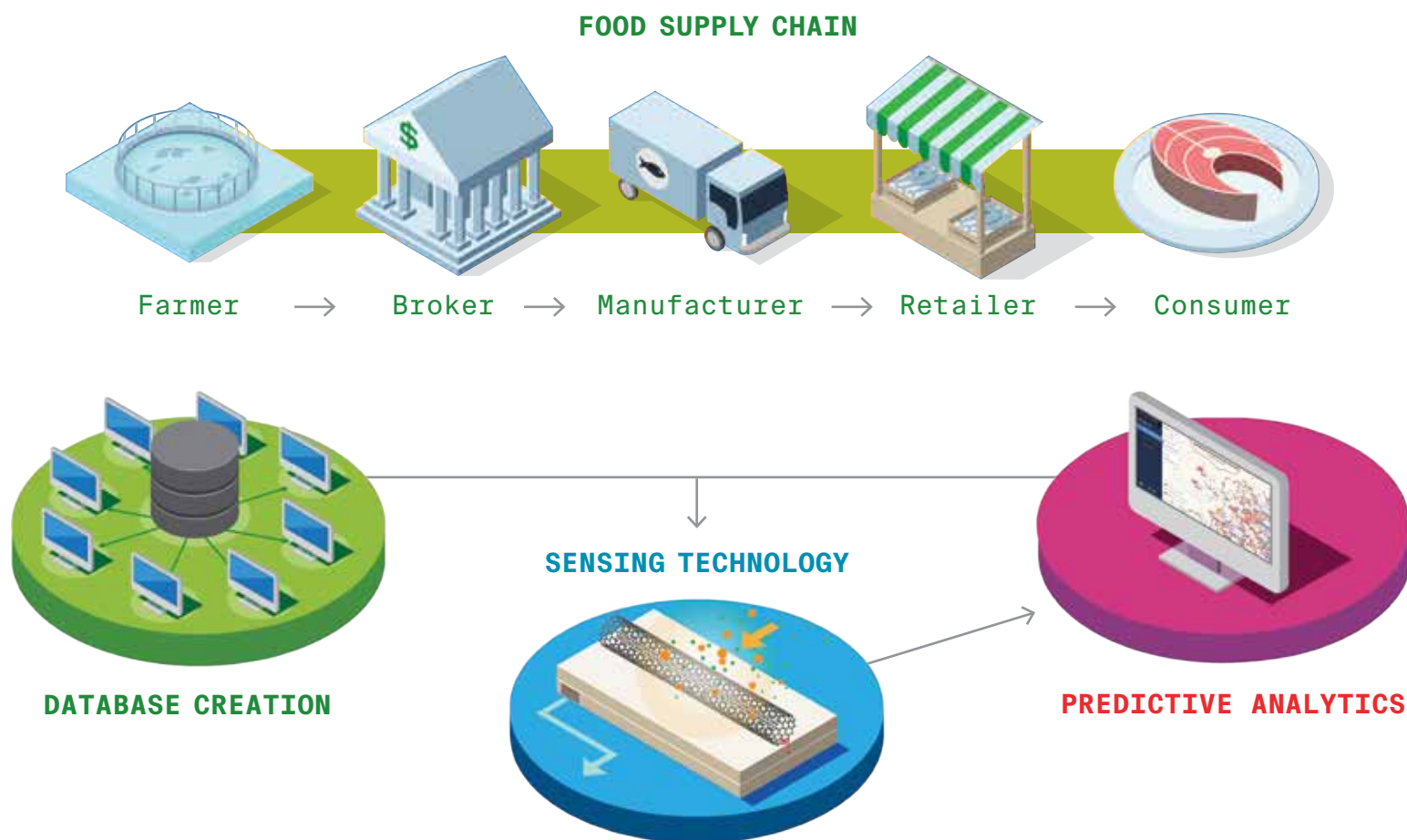
Brown’s current research, which explores a shift toward more energy-efficient and environmentally forgiving modes of farming, is aligned with that theme. While people today focus on the growth of financial indicators, she says, “we ignore the phenomenal growth around us—the ability of plants to create biomass, turn carbon dioxide into oxygen, and fill our soils with nutrients. That’s the kind of growth that’s really radical, and that’s the kind of growth we should be promoting.” —Steve Nadis

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

(↗)

MORE PERSPECTIVES ON THE PANDEMIC FROM MIT SHASS

<https://bit.ly/PandemicPortal>



Building Safer Food Systems

New initiative addresses hazards throughout the supply chain

The Covid-19 pandemic has drawn new attention to the safety of the global food supply. Early reports suggested that SARS-CoV-2, the novel coronavirus that causes this disease, may have begun its deadly spread from the Huanan Seafood Wholesale Market in Wuhan, China. While we may never know the true origin of the disease, scientists agree that markets that sell fresh meat and fish create the ideal conditions for viruses to jump from animals to humans, and to spread from humans to other humans. The 2002 SARS outbreak began at a similar market in China.

Viruses are just one of many potential threats along the food chain that leads from farm to market to table. Those threats have proven deadly. In 2008, milk and infant formula tainted with the chemical melamine sent more than 50,000 Chinese babies to the hospital, killing six. An outbreak of the foodborne bacterium *Listeria* caused nearly 200 deaths in South Africa between 2017 and 2018. A strain of *E. coli* bacteria traced back to romaine lettuce from Yuma, Arizona, sickened hundreds of people across 36 US states in 2018.

This summer, the MIT Sloan School of Management launched a new initiative to help keep our food safe: the Food Supply Chain Analytics and Sensing Initiative (FSAS). “This is a global challenge with relevance to every country on the planet,” says Retsef Levi, the J. Spencer Standish Professor of Operations Management and faculty director of FSAS. “Food and agriculture supply chains have major and multifaceted

impact on human health and pose major challenges to governments and industry across the globe. We hope that our multidisciplinary work can help inform policies and industry practices and build better global food systems.”

FSAS will develop and disseminate new analytical tools that can assess and promote food safety around the world. “The ultimate goal is to revolutionize how risk is managed in food supply chains,” says Stacy Springs, executive director of FSAS. “To do that, we need to extract data, map supply chains, and create the automated tools that will help us identify the areas where the greatest risk resides.”

The multidisciplinary initiative involves faculty and graduate students from MIT’s School of Science and School of Engineering as well as MIT Sloan, and it will work in partnership with additional academic institutions, industry, government agencies, and nongovernmental organizations. There are three areas of work: management of food safety and adulteration risks; design and optimization of agricultural supply chains and markets; and issues of food access and food waste.

The agricultural supply chain study is of particular importance to developing countries, where agriculture is often the largest source

of employment and where struggling farmers or merchants may be tempted to cheat on hygiene or even poison their produce. “If you don’t look after the welfare of food producers, you put them in a situation where bad practices and food fraud can occur,” Levi explains.

Solid research foundation

In 2013, Levi and Springs began work with the US Food and Drug Administration to develop predictive models for managing risks from the global food supply chain. The initial focus of this contract was on imports from China. FSAS members also received seed funding from the MIT Abdul Latif Jameel Water and Food Systems Lab to work on research ranging from supply chain mapping to the development of bioassays for identifying unknown adulterants. Three years later, Levi, Springs, and Yasheng Huang, all principal investigators at FSAS, received a \$7.5 million grant based on these earlier works to support a broad food-safety study in China. They then took a team of MIT faculty and students on a research trip to China in 2018. “The team’s first focus was on freshwater aquatic supply chains,” Springs says. “We met with many future collaborators, identified public data sources that could support the research, and visited several wholesale markets in Zhejiang province. From there, Levi’s team set a course to mine much of the available food safety data, create structured databases, and build tools to automate that process.”

MIT’s food safety work has since expanded with faculty and research in India, Indonesia, and Thailand. While the scope of FSAS is global, the initiative will tailor its approach to each region. “Food supply chains in China, for example, are even longer and more complex than they are in the United States,” explains Huang, who is also the Epoch Foundation Professor of International Management at MIT Sloan. “And unlike in the US, Chinese farms are extremely decentralized, with tens of millions of individual farmers. It is challenging to identify the best point along the chain to intervene.”

“If you don’t look after the welfare of food producers, you put them in a situation where bad practices and food fraud can occur,” Levi explains.

Although some data on food safety and adulteration in China is available to the public, the information is scattered across hundreds of different sites and publications. Analyzing these multiple sources and consolidating data on aquatic food chains led Huang and his colleagues to an important insight: Chinese wholesale markets were a key source of risk in that country’s food supply chain.

Unfortunately, that insight alone will not lead to greater food safety.

“We need to come up with measures for things we don’t typically measure,” says Huang, whose research centers on government regulations. “A measure for how transparent each local administration is about food safety issues. Or a measure that tells us how actively that local government enforces food safety. No one is measuring this sort of information. It’s up to academics to come up with new ways to harvest and analyze this data.”

Focus on farms

Along with creating and analyzing metrics on wholesale markets, FSAS will also create platforms to collect data from smallholders and family farms—the so-called “first mile” of the food supply chain, which provides more than 50% of the world’s calories. It’s a tough job. “We have very little information about this informal first mile,” says Joann de Zegher, the Maurice F. Strong Career Development Professor and assistant professor of operations management. “But most of the smallholders have mobile phones, allowing us to develop and leverage mobile-based platforms to help them make better decisions.”

De Zegher believes creating a digital platform for smallholders could augment food safety as well as promote sustainability. “Right now, if you’re sourcing from smallholder farms, it’s difficult to know where a specific product or lot comes from,” says de Zegher, who studies palm oil production in Indonesia. “With digital tools, we could trace the origins of a shipment.” Such work could provide food safety information and other benefits, such as determining whether the palm oil came from an area that was deforested illegally.

While enhancing food safety across the globe, FSAS also endeavors to help smallholder farmers thrive. “We and our partners are working to develop platforms that help inform farmers of best practices. The platforms will also create access to new markets for farmers,” says Yanchong Karen Zheng, the Sloan School Career Development Professor, associate professor of operations management, and an FSAS collaborator. “Right now, these farmers have very limited choices of where they can sell their produce.” —Ken Shulman



The research team interviews farmers at Jolhpura Village's Nursarai Block in Bihar, India.

PHOTO: COURTESY OF FSAS

A Model Approach to Public Health

IDSS researcher applies data science to tracking Covid-19

When Marie-Laure Charpignon started her PhD at the MIT Institute for Data, Systems, and Society (IDSS) in 2018, she never imagined that a year and a half later, the very same data-science skills she was developing would be needed to tackle one of the biggest public-health problems of this century: Covid-19. Yet Charpignon suddenly found herself consumed by Covid-19 research, often working late into the night to model the pandemic's deadly spread.

Charpignon's research took this unexpected turn in early 2020 as Covid-19 hit the United States. Her mentor, Maimuna Majumder SM '15, PhD '18, invited her to join the newly formed Covid-19 Dispersed Volunteer Research Network, a broad-based effort to put scientists to work fighting the pandemic. Since then, Charpignon has been working with others to model the spread of Covid-19 within different states.

To estimate how quickly the virus is likely to propagate, the model incorporates information on current public health restrictions, the distribution of families, demographics on age and preexisting conditions, and patterns of contact. Researchers can then adjust model inputs to predict how different public-health policies may affect the spread. For example, the model showed that in Georgia, Florida, and Mississippi, implementing initial quarantine lockdowns a week and a half earlier would have saved hundreds of lives—and continuing those lockdowns for several weeks longer could have saved thousands.

Charpignon says the goal is not only to understand spreading dynamics but also to forecast undocumented Covid-19 cases, which can inform vaccine purchase and distribution. "It's really like resource planning," she says. "Once you have an estimate, you can start your resource budgeting."

Until a two-year stint at Microsoft Education, where she saw firsthand how schools struggle to address health issues such as nutrition and disease prevention, Charpignon never considered the intersection between data science and public health. It was clear to her then that public health was a field that needed more research. The experience solidified her next step: pursuing a PhD at IDSS, which focuses on applying advanced analytical tools to complex societal challenges. "IDSS is very interdisciplinary," she says. "I think this is the future."

Alzheimer's research

At IDSS, Charpignon uses computational tools to explore large-scale questions in public health with a focus on nontraditional data sources. Her main project centers on drug repurposing for Alzheimer's disease. "There is no cure for Alzheimer's, but as we get older, we all start taking multiple medications," says Charpignon, who is advised on the project by Roy Welsch, the Eastman Kodak Leaders for Global Operations Professor of Management, and Stan Finkelstein '71, a senior research scientist with IDSS who has been working on repurposing drugs for many years. The research team began to ask whether some of the drugs that we already take, specifically those for diabetes, might reduce the risk of Alzheimer's.

To address this question, the team is analyzing tens of thousands of electronic-health records in the United States and the United Kingdom and pairing findings with data on how neural cells respond to different drugs. Early results suggest the diabetes drug metformin may be linked to less severe dementia, a connection that the team is investigating further.

Charpignon is also working on other Covid-19 projects. In one, she and her teammates are focusing on social media, examining how sentiment about the Centers for Disease Control and Prevention (CDC) and mask wearing is evolving on Twitter. The researchers extract a representative sample of tweets mentioning the CDC and masks and classify each by sentiments such as fear, anger, and trust or mistrust. They then track how sentiment changes over time and evaluate what happens when influential people express their opinions.

"What we want to understand is how to frame health messaging on social media to drive or influence people," Charpignon explains. "I think it's important to do surveillance of reactions on social media and adapt health messaging to this."

If there is a silver lining to Covid-19, Charpignon says it is bringing newfound attention to public health as a vital area of study. "I think there is a lot of low-hanging fruit" in public health research, she says, and the field will benefit greatly from additional recognition and resources. "Public health should be the responsibility of everyone," she adds. "There is really a lot of optimization that could be done."

—Catherine Caruso SM '16



Charpignon

Lessons from an Old Enemy

Jacquin Niles employs biological engineering to fight malaria

Nearly half a million people die each year from malaria, a disease that has been part of the human experience since the dawn of time. With characteristic symptoms of high fever, chills, and weakness, malaria is caused by any of several *Plasmodium* parasite species, with *P. falciparum* being responsible for the highest mortality. While the mosquito-borne pathogen has been eradicated in some parts of the world, including the United States and Europe, the developing world continues to suffer.

“An effective vaccine is still highly sought, even after decades of effort; one has recently been approved for clinical use, but it provides only about 30% protection that rapidly wanes,” says Jacquin Niles ’94, PhD ’01, professor of biological engineering and a physician scientist by training. “We have to continue moving forward and doing better.”

To that end, Niles has dedicated his career to fighting malaria.

Disease impacts

About 90% of malaria deaths occur in Africa, with children under five years being most commonly afflicted. Raised in the Caribbean, Niles says he is very familiar with the human cost of disease. “I grew up in a context where exposure to different infectious diseases was always a concern; you could see their impact on people and their livelihoods,” says Niles, who is also the director of the MIT Center for Environmental Health Sciences and an associate member of the Broad Institute of MIT and Harvard. “Seeing this impact has been an important motivation for me to pursue research in this field.”

Niles’s career provides a window into the long, uphill journey scientists face in fighting a disease such as Covid-19. “The process of bringing a new drug to market typically has a lead time of about a decade from initial discovery to ensuring that the drug can be safely and efficaciously used in humans,” he points out. He and his team have been working for more than a decade to establish new ways to disrupt the malaria parasite’s life cycle.



“The lab spent a lot of time developing the basic technologies we needed to genetically manipulate the parasite so we could more precisely define its vulnerabilities to help propel drug discovery.”

Battling malaria today centers on treatment with antimalarial drugs, but this has drawbacks. “These parasites are resilient,” Niles says. “Resistance to mainstay antimalarial drugs occurs fairly commonly and then spreads around the globe. Some drugs work very well but for a limited time.” Understanding the strategies the parasite uses to survive can provide new insights into possible therapeutics.

Most recently, Niles and his team have focused on how the parasite metabolizes heme, the molecule that makes blood look red. Malaria parasites spend much of their lives in human red blood cells, consuming hemoglobin and releasing heme, which can be toxic but may also be used to support growth. “Our work is revealing aspects of a complex metabolic network the parasite uses to walk a razor’s edge in regulating the balance between beneficial and harmful effects of heme,” he says. “Actually, it’s amazing that a pathogen adopting such a potentially dangerous lifestyle could be among the most successful.”

Disrupting this balance in heme metabolism provides an opportunity for new therapeutics. “We’ve been focused on understanding if there are additional players involved in heme metabolism that would give us new ways to interfere with this process for therapeutic purposes. Targeting this pathway has provided some of the most successful antimalarial drugs

used clinically—namely chloroquine and related drugs,” says Niles. Combining drugs with different modes of attacking the pathogen will be critical to fighting drug resistance, Niles adds. This approach has proven successful in fighting other infectious diseases, such as HIV.

While malaria and other killer infectious diseases of the developing world rarely get attention commensurate with their impact on human lives, Niles has a hopeful attitude toward fighting pathogens, and that includes the Covid-19 virus. “The urgency with which resources have been mobilized to combat the Covid-19 pandemic has been wonderful,” he says. “It will likely require a similarly intentional marshaling of resources to eliminate malaria and reduce the human health burden due to neglected diseases. With continued effort and a diversity of ideas focused on these problems, I am optimistic these goals are attainable.”

“The urgency with which resources have been mobilized to combat the Covid-19 pandemic has been wonderful,” Niles says. “It will likely require a similarly intentional marshaling of resources to eliminate malaria.”

Toward Faster Drug Development

Lab of J. Christopher Love forms consortium to speed manufacture of therapeutics

“Our lab aims to transform biopharmaceutical development from discovery to manufacturing to make new drugs as accessible as possible globally,” says J. Christopher Love, the Raymond A. and Helen E. St. Laurent Professor of Chemical Engineering. “Pursuing a Covid-19 vaccine has been the perfect chance to advance these ideas—a real live-fire test for us.”

Under pressure from the pandemic, Love and his team worked not only to design and build potentially life-saving vaccine candidates but also to further his larger vision: changing the drug-development pipeline to get treatments to patients faster. On June 22, in the midst of Covid-19 research, he announced the AltHost Consortium, an MIT-led group for open-access sharing of research and information with pharmaceutical giants Amgen, Biogen, Pfizer, Roche, and Sanofi. By leveraging contributions from this consortium, and harnessing his lab’s novel methods for evaluating and rapidly manufacturing biologically based medicines, Love was able to fashion coronavirus vaccine possibilities in record time.

“Our work thinking about how to respond most efficiently in urgent circumstances prepared us for the current crisis,” says Love. “We were able get out of the gate very quickly.”



Tackling Covid-19

Prior to the pandemic, the Love Lab, supported by the Bill and Melinda Gates Foundation (also an AltHost member), had been devising ways to produce and disseminate millions of doses of low-cost vaccines, especially for infectious diseases affecting the world’s most vulnerable populations. Such capabilities for generating vaccine candidates might also, Love and his team recognized, be necessary in case of a pandemic.

That need arrived sooner than they imagined. In February 2020, research sponsors presented an urgent challenge to Love: Could you create a Covid-19 vaccine candidate by the end of the month?

Love’s lab, which resides in the Koch Institute for Integrative Cancer Research, brings together graduate research assistants and technical experts in chemical and biological engineering, immunology, and the genomic sciences. This multidisciplinary compass underpins the team’s pathbreaking approach to both drug discovery and manufacturing, an approach intended to skirt the pitfalls of the conventional process for bringing new drug candidates to production.

Currently, vaccines are manufactured in centralized facilities that make large quantities of a single type at a time. If something goes wrong during production, millions of doses can be lost. Manufacturers cannot respond quickly to new disease threats because it can take many months to grow the necessary biological components in such conventional facilities or to reconfigure these facilities to accommodate a different vaccine product.

“To avoid these kinds of bottlenecks, we must invent a simple, efficient method for manufacturing,” says Sergio A. Rodriguez, a third-year PhD student in biological engineering and a member of the Love Lab. “That is precisely what our lab has set out to accomplish.”

The Love Lab’s platform uses genetically engineered yeasts as biofactories for proteins that are the core constituents of many pharmaceuticals. Applying techniques such as CRISPR-Cas9, a genome editor, the lab can modify yeasts in a matter of days. “We are essentially tuning strains of yeast to produce specific kinds of drugs such as vaccine candidates,” says Neil Dalvie, a fifth-year PhD student in chemical engineering and a graduate research assistant.

Through a series of iterations, researchers test and tweak target proteins, focusing simultaneously on the effectiveness of their products and on whether the manufacturing process yields these products reliably and in sufficient volume to ramp up production.

This kind of innovative drug development, which Love describes as “on-demand biomanufacturing,” could one day enable smaller pharmaceutical companies, stocked with the right ingredients and genetic information, to generate products wherever they are needed.

“It is a streamlined approach where engineering, host biology, immune response, and manufacturability are integrated, giving us an opportunity to design for low-cost medicines that could reach potentially billions of patients,” says Love.

Professor J. Christopher Love in his lab at the Koch Institute for Integrative Cancer Research with Neil Dalvie at the bench.

PHOTOS: M. SCOTT BRAUER



Wearing masks to adhere to protocols put in place during the Covid-19 pandemic, PhD students Elvin Yang and Neil Dalvie, left, and Sergio A. Rodriguez, below, conduct research in the lab of Professor J. Christopher Love.

Pandemic work

When MIT shut down research facilities in March, the Love team continued its vital efforts on Covid-19 vaccine discovery and manufacture. Only four staff at a time were allowed in the lab. While Love and the rest of the group contributed from home, Dalvie and three other graduate students were deemed essential workers and stayed on campus. They seized the chance to play leading roles in significant research.

“Once the Covid-19 work began, all of us realized the broader impact of our research on the world, and that we must do our best, and quickly,” says Rodriguez.

The immediate goal was to produce a vaccine based on the spike protein used by the coronavirus to latch onto receptors in human cells, the first interaction of the virus in its attack. “The idea is that a vaccine that resembles this spike protein would prevent this interaction by generating an immune response where antibodies would neutralize the spike before it binds to the cell,” says Dalvie. The core team set out to transform *Pichia pastoris*, the host yeast, into an effective biofactory for this target protein.

This work proved a major change of pace for all of them—longer-than-usual days with the added burden of social distancing and constant pressure. The scene on campus sometimes seemed surreal.

“It was weird to see everything so empty and quiet,” says Elvin Yang, a third-year chemical engineering PhD student. “But I was really glad to be in the lab, where it felt like I was working on tangible things and generating results.”

This intense round of research leveraged the Love Lab’s interdisciplinary culture. “Our lab is designed to encourage collaboration, and to ensure that each of us gains a holistic understanding of the host organism and biomanufacturing process,” says Rodriguez. “We didn’t get to say, ‘I’m the one who does yeast purification.’”

“Challenges in production can best be solved when everyone knows the molecular design, host biology, and engineering processes,” says Love. “This is what makes our lab different.”

Vaccine candidate

In just 28 days, the Love Lab managed to produce its first version of a Covid-19 vaccine candidate. But creating a potential vaccine is far from the conclusion of drug R&D. Researchers must also demonstrate that the vaccine can safely engender an effective immune response in animal models and humans. Just as important, the team must prove that its

“Challenges in production can best be solved when everyone knows the molecular design, host biology, and engineering processes,” says Love. “This is what makes our lab different.”

manufacturing approach is agile enough to respond rapidly to potential virus mutations and that its biomanufacturing platform can scale up sufficiently. “To address the pandemic, the world will need billions of doses,” says Love.

To that end, last spring the lab began sending out vaccine components, including its engineered yeast cell lines, to multiple partners around the world for trial manufacturing and evaluation—progress made possible, in part, by the collective research of the AltHost Consortium.

“With our Covid-19 work, we have begun modeling ideas for sharing cell strains and providing access to advanced tools so we can all move forward together on the development of life-saving drugs,” says Love. “I feel fortunate that in these incredibly challenging circumstances, we are able to demonstrate our vision for how we might transform the conventional state of biopharmaceutical manufacturing.”

—Leda Zimmerman



Public Health Drives Undergrad

Shulammit Lim works toward better access, information for all

Shulammit Lim '22 is pursuing a passion for public health that began in high school, when she volunteered to support free community health screenings in Kansas City. Anyone who stopped by could get simple but important metrics checked: weight, blood pressure, and blood sugar.

"I have close family members who are diabetic, and I know how important it is to monitor a person's blood sugar," says Lim. "But I kept seeing people with high blood sugar readings and realizing that proper treatment was often out of reach for them." Troubled by the financial and communication barriers to health care, she resolved to learn more.

"I was frustrated by the pain people have to endure due to limited access to proper health care," she says. "I believe that implementing preventative care measures at the community level could greatly reduce the impact of severe health problems."

Now a junior at MIT thanks to support from the Skipper Greer and Joseph L. Kirk Scholarship Fund, Lim is continuing health-related work both inside and outside the classroom. She is majoring in computer science and molecular biology and says one of the lessons she takes from the current global health crisis is the power of applying computational tools to scientific data. "Scientists have to make huge collections of biological data understandable, and the conclusions drawn from that data can drive public-policy decisions," she remarks.

Lim says the mix of computer science and biology in her major is enabling her to build a foundation in basic programming while simultaneously gaining strength in core science subjects such as organic chemistry and cell biology. "I've always been drawn to computational projects," she says. "By using computational methods, I can solve problems and answer questions with only me and a computer. I don't even need a physical lab space!"



In fact, Lim was able to work remotely over the summer. MIT's Undergraduate Research Opportunities Program helped her secure a position with the MIT Laboratory for Computational Physiology on a project with PhysioNet, a data repository for biomedical research. Her project centered on developing a new feature that tracks and displays data usage metrics. "This project drew on my knowledge from taking 6.009 Fundamentals of Programming," Lim says, noting that the project required her to use Django, a Python-based web framework.

Extracurriculars

Outside of work and class, Lim serves on the executive board of the MIT Global Health Alliance, a student organization that promotes global health equity and community empowerment through partnerships with US-based and international nonprofits. She has created and led lessons on such topics as nutrition, malaria, and the dangers of health misinformation.

Lim has also volunteered with Harvard Medical School's Family Van, which provides preventative health care screenings and health information to people in underserved

communities. When the coronavirus hit, she worked with other volunteers to create a Covid-19 brochure listing local resources for people in need. "I was impressed with the number of organizations making themselves available even in a pandemic," she says.

Covid-19 brought an abrupt and disappointing end to her in-person participation in the MIT Chamber Music Society; Lim enjoyed playing the violin in a string quartet. However, she and her fellow musicians experimented with recording themselves and stitching the separate recordings together. "There was a big learning curve," she says, "but we managed to make it sound almost like we're in the same room. It's really fulfilling to have something to show for all the hard work!"

Looking ahead to life and career after MIT, Lim hopes to combine computer science and software expertise with a passion for public health that has been reinforced by the events of 2020. "I was always interested in medicine, and in recent years I have been drawn further into human health as a whole, the factors that affect it and how to improve it. Technology can play a big role, and I would love to help apply technology toward health equity." —Christine Thielman

Neighborhoods Under Pressure

Mariana Arcaya studies how housing stress increases health risks

As Covid-19 spread across Massachusetts in March, the hardest-hit communities weren't necessarily those with the highest poverty rates or densest housing. Many did, however, have one thing in common: they were selected years ago as sites for the Healthy Neighborhoods Study, a project examining the link between housing and health.

Since 2015, Mariana Arcaya MCP '08, associate professor of urban planning and public health and associate head of the Department of Urban Studies and Planning (DUSP) at MIT, has been leading the study with Vedette Gavin at the Conservation Law Foundation and with community-based organizations.

Arcaya and her fellow researchers set out to understand the health implications of rapid neighborhood change, identifying six municipalities and three Boston neighborhoods that were facing real estate development pressure that community members and the researchers feared could damage health. "In rapidly gentrifying areas, economically and socially vulnerable families have set up their lives in places that until recently were affordable," says Arcaya. "Now, all of a sudden, they're not affordable."

Study participants have reported that the changes in their neighborhoods, including increasingly unaffordable housing, have caused financial

stress and overcrowding, factors that can increase susceptibility to a viral pandemic.

Of the six municipalities being studied, four turned out to be among the five communities hardest hit by Covid-19 in Massachusetts this summer. Arcaya points out that high housing costs can spur poorer residents in gentrifying areas to double up or rent out rooms in their homes. These same residents typically can't afford to stockpile groceries to shelter in place, and many had to continue working, often in service jobs, increasing their risk of Covid-19 infection.

"Social distancing is a privilege," says Arcaya, who with her team wrote an open letter in March urging public officials to factor community stressors into their pandemic response. "Covid has made obvious to everyone what communities have been saying for years—that insecure and unaffordable housing, jobs that don't pay enough to make ends meet, and a lack of paid sick leave and other social protections are public health problems."

The Healthy Neighborhoods Study's "participatory action research" approach is still relatively uncommon in academia: researchers work with community-based organizations, which then recruit residents to codesign survey questions, collect data within their own communities, and analyze and interpret results collaboratively. That approach is slower than typical academic research, but it has led to new insights, Arcaya says.

"When trying to understand displacement risk related to gentrification, for example, we listen to the precise words people use, and they are saying, 'People are being pushed out,'" Arcaya says. Such resident reports led her and her colleagues to request consumer credit data from the Federal Reserve; analysis of that data by DUSP doctoral student Madeleine Daepf, recipient of a DUSP graduate student fellowship, revealed patterns of migration out of Boston for residents of the study communities.

"Participatory action research gives us a different perspective on Covid-19 centered on understanding what creates unequal types of risk, for whom, and what can be done about it," explains Arcaya. By investigating these topics, Arcaya and her team hope to broaden the conversation about what factors put communities at risk for health consequences, particularly in urban environments. "We need to listen to communities when they say the pressures they are under are unhealthy and unsafe. Covid is making clear that secure, affordable housing for everyone should be a public health priority."

—Michael Blanding

People in Chelsea, Massachusetts, one of the communities hardest hit by the coronavirus, wait in line for food distributed by the National Guard in April 2020.

PHOTO: JOSEPH PREZIOSO / AFP
VIA GETTY IMAGES



Bringing Down Mercury

Noelle Selin explores toxin's history, works to change policy

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

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

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

The mercury mine in Almadén, Spain, (right) produced tons of mercury before closing in 2002.

PHOTO: JOSE MANUEL REVUELTA LUNA / ALAMY STOCK PHOTO

Legacy of pollution

Selin runs atmospheric models to determine where the mercury we see today comes from. Coal burning is one culprit, since mercury is a common coal contaminant. Another significant source is artisanal and small-scale gold mining in developing countries. But the mine in Almadén, classified now as a UNESCO World Heritage Site, is just one example of how human history and mercury are intertwined.

The thing about mercury as an element is that it's stable, so it doesn't break down like DDT, PCBs, and other, more chemically complex pollutants. It cycles between the atmosphere and the ocean for centuries. Mercury easily evaporates, travels long distances in the air, and then rains back down onto land and into water. "So we're actually living with the legacy of both past and current mercury pollution," Selin explains.

For instance, in the 1500s, mercury was used as part of a process to extract silver from ore

in South America. Some of this silver returned to Spain to be transformed into, among other things, the urns and altarpieces that the Selins saw at the Seville Cathedral earlier this year. So it's quite possible that this same mercury from half a millennium ago is still circulating in the world. "And now it's in your tuna," Selin adds. That's because seafood—especially swordfish and tuna—bioconcentrate the element in the form of methylmercury, which harms neurological development and cardiovascular health even at low exposures. (This is why it is particularly dangerous for children and pregnant women to eat large quantities of certain fish.)

Linking science to policy

Selin's interest in these issues has been percolating for years. As an undergraduate at Harvard University in the late '90s studying environmental science and public policy, she interned at the US Environmental Protection Agency (EPA) in Washington, DC. She witnessed firsthand the negotiation of a global treaty regulating persistent organic pollutants, chemicals like DDT and PCBs, which had recently been found to travel long distances and accumulate in food sources. Selin went to Stockholm for the signing of this treaty in 2001 (which is where she met Henrik, incidentally).

During the George W. Bush administration, which was skeptical about starting negotiations for a global treaty controlling mercury, Selin demonstrated through her graduate work that both domestic and international action were necessary to address mercury contamination in the United States. When Barack Obama became president, Selin's research in part helped persuade the new EPA administrator to change the country's position and support a worldwide treaty on mercury.

In early 2013, by this time a professor at MIT, Selin took 10 graduate students to Geneva to watch the final negotiating session for this treaty, staying up all night until it was complete. Four years later, that treaty came into force. It was called the Minamata Convention, named after the town in

Japan where methylmercury was first identified in those who had eaten contaminated fish.

These days, Selin continues to use data on where mercury comes from, how it's transported globally, and its impact on human populations in her modeling to advise and strengthen global policy on pollution and climate change. "Part of my work is informing negotiators of the global treaty how they can better manage mercury and evaluate how effective their strategies are," says Selin.

Domestically, she's also modeled how different policy directions would impact American consumers. It's an issue of particular relevance since the federal Mercury and Air Toxics Standards, established in 2012, were threatened earlier this year when the EPA "rolled back the finding that it was 'appropriate and necessary' to regulate mercury," says Selin. She testified before Congress in advance of the rollback, hoping to support a future legal challenge to the change.

Selin is also the director of the MIT Technology and Policy Program, where she works with students to use science and engineering to shape policy, finding ways to "improve what we do so it's more impactful." The historical context remains central to Selin's approach. "You have this rich thousand-year-plus history of people interacting with mercury," she says. "Individual societies and governments have made decisions about how best to balance the risks and dangers and manage these threats to human health and well-being."

Many people were harmed by mercury before enough evidence accumulated to persuade communities to stop using the heavy metal. It's this sort of transition that Selin sees influencing other urgent sustainability efforts, including climate change. At this stage of her career, she says she's using her work on mercury and other toxins "as examples of the challenges facing humanity, and how best to take a multidisciplinary approach to make broad change in the world."

—Ari Daniel PhD '08

"We're actually living with the legacy of both past and current mercury pollution," Selin explains.



“A world does not predate its images. It is shaped by them.”—*The World as an Architectural Project*

Global Perspective

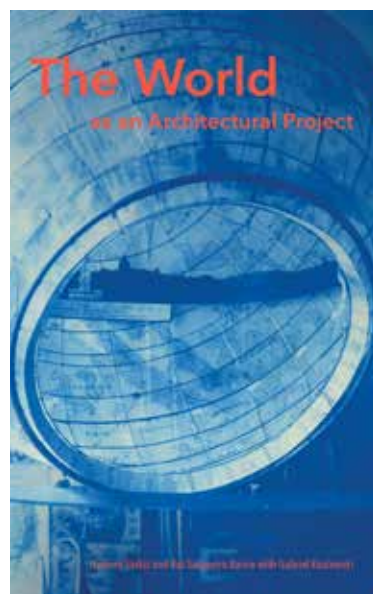
An excerpt from *The World as an Architectural Project*

Today, encounters with the planet are a quotidian phenomenon, dulled by increasing international relations and new means of communication. At the same time, too often we face the globe in darker, more somber ways. Contemporary perceptions of the world are unavoidably associated with...urban expansion across the planet; transcontinental migratory flows; environmental hazards; sea level rise; and global warming. All these changes bring the world scale within our daily experiences and, without a doubt, to the core of our most pressing social concerns.

Architecture’s responses to these contemporary, global challenges has mostly favored technical solutions. Architects are addressing environmental questions and global warming through a new ethics of construction supporting hard choices of renewable materials and passive environmental systems. On another front, when mobilized to respond to the problems of refugees, migratory movements, and other humanitarian crises, architects justifiably tend to switch hats and take on the role of relief workers focused on shelter....

...A different, complementary mode of operation [is] to understand the spatial, technological, and social processes that are shaping the planet, in order to define types and scales of architectural intervention that can challenge the ways in which globalization takes place.

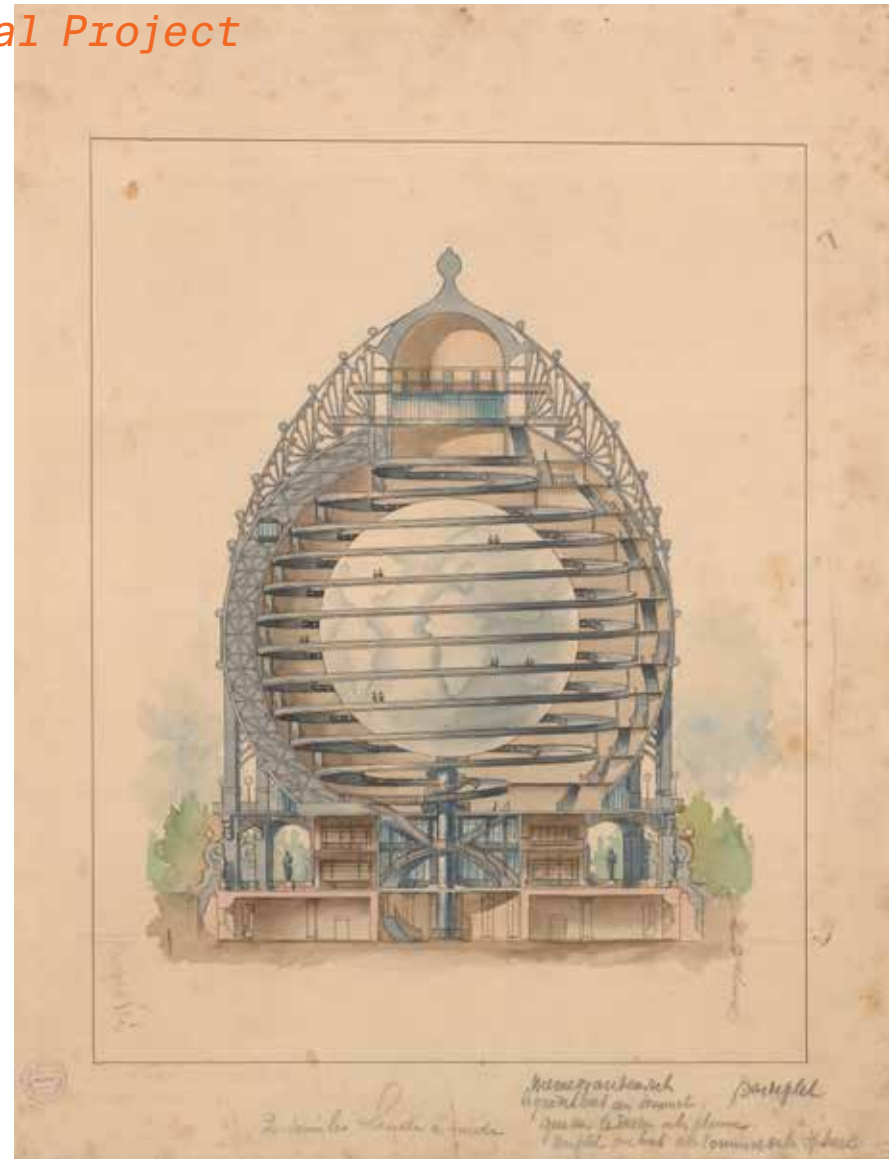
The purpose of this book is to reconnect this trend of contemporary architectural inquiry to a broader disciplinary history that has shaped the ways in which we live and think about our present.



From *The World as an Architectural Project* (The MIT Press, 2019), by Hashim Sarkis,* dean of the MIT School of Architecture and Planning (SA+P) and SA+P instructor Roi Salgueiro Barrio with SA+P research associate Gabriel Kozlowski SM '15.

The book features 50 speculative projects, three of which are highlighted here.

*Sarkis will serve as curator of the 17th La Biennale di Venezia to be held in 2021.



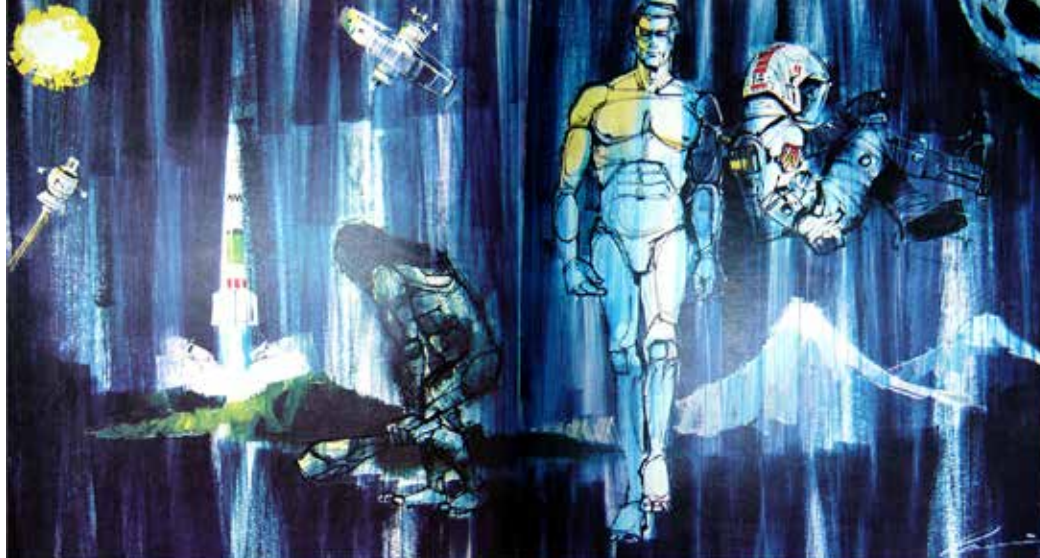
PROJECT: Terrestrial Globe at the Scale 1:100,000

In 1895, the French geographer Élisée Reclus proposed constructing an enormous globe (1:100,000 scale) for the Paris Exhibition of 1900. It was never constructed. “The desire to realistically replicate the planet gives its most literal form to an understanding of architecture as an epistemological instrument,” the authors write. “Reclus’s Terrestrial Globe reveals the increasing need in the late nineteenth century to understand how architecture can respond to the human transformation of the planet.”

Terrestrial Globe design by Élisée Reclus. The globe is surrounded by a spiral system of staircases and elevators.

ÉLISÉE RECLUS, “PROJET DE CONSTRUCTION D’UN GLOBE TERRESTRE À L’ÉCHELLE DU 100.000E,” IN REPORT OF THE SIXTH INTERNATIONAL GEOGRAPHICAL CONGRESS, ED. THE SECRETARIES (LONDON: JOHN MURRAY, 1896), 625.

EXCERPTED FROM *THE WORLD AS AN ARCHITECTURAL PROJECT* BY HASHIM SARKIS, ROI SALGUEIRO BARRIO, AND GABRIEL KOZLOWSKI © 2019 MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

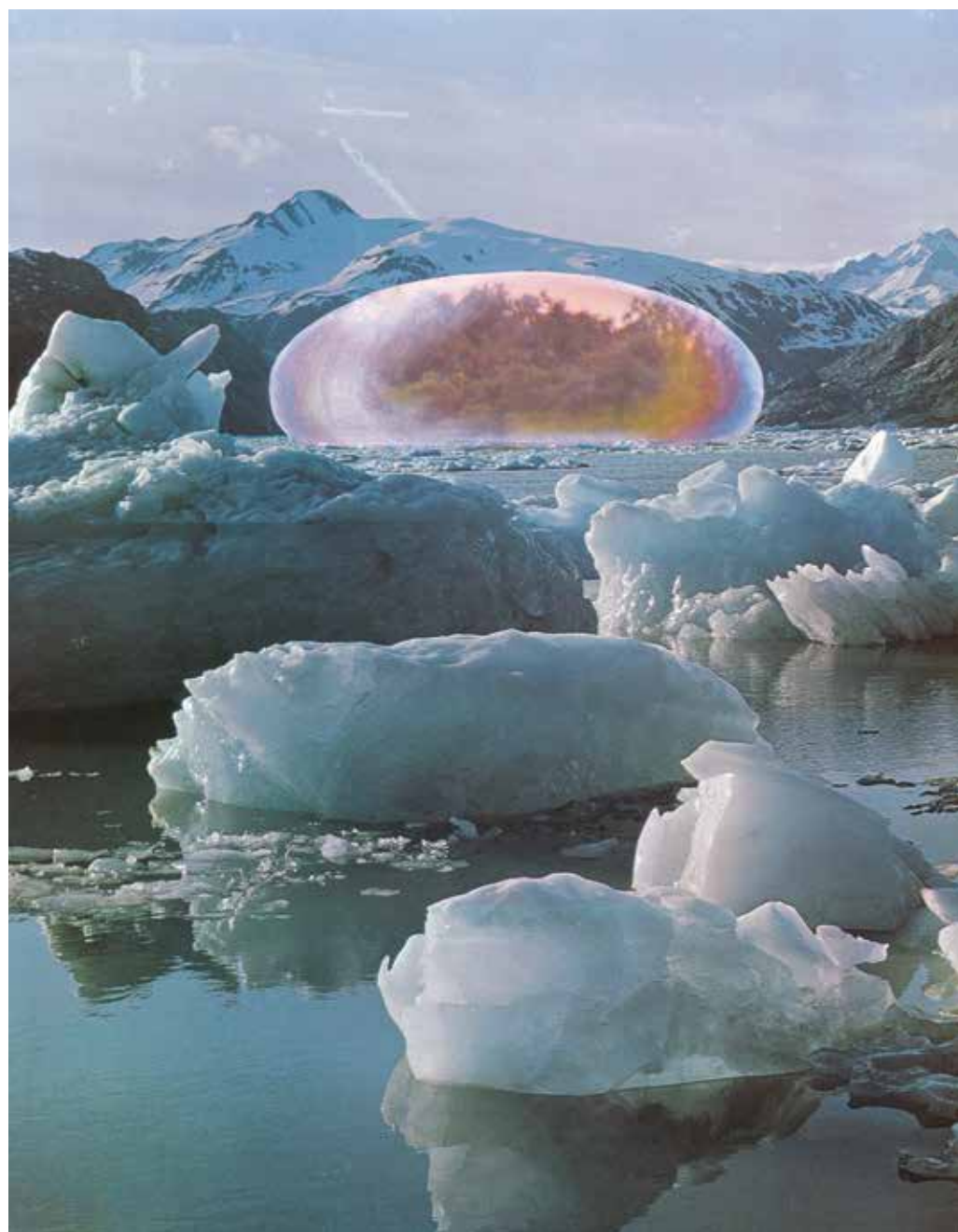


PROJECT: The World in the Cybernetics Era

Architect Sergio Bernardes was one of the most important and controversial figures of late modernism in Brazil, according to the authors. Having conceived a 1965 project, “Rio in the Cybernetics Era,” that centered on “the city’s future status within an increasingly integrated planet,” Bernardes later expanded his futuristic vision. Ultimately, he advocated “the total merging of ‘Man’ and ‘Earth’ systems in a new entity: ‘Homogeofusion (homogeofusao).’”

**Bernardes's Man
in the Universe, 1965**

BERNARDES, SERGIO. "TERRISMO: UMA IDEOLOGIA." IN SERGIO BERNARDES, EDITED BY KYKAH BERNARDES AND LAURA PEREIRA, 215 AND 293. SÃO PAULO: ARTVIVA EDITORA, 2010.



PROJECT: Gates

“Since the mid-1970s, the goal of architect and visual artist Juan Navarro has been to express the universal constituents of the natural environment, such as light, atmospheric effects, and gravity,” the authors write. A Spanish architect, Navarro was a research fellow at the MIT Center for Advanced Visual Studies from 1971 to 1975. “Navarro explores how to create forms of architecture and artificial systems that can contribute to the creation of a world-system.” Mechanisms and spaces for producing and receiving information—what Navarro calls “gates”—are a central concept of his work. Navarro envisions environmental art at the world scale, including capsules (pictured) that transport ecological systems.

**Navarro's Proposal for the
Increasing of Ecological
Experiences. Transferring
ecosystems, 1972.**

KEPES, GYÖRGY. ARTS OF THE ENVIRONMENT. VISION + VALUE SERIES. NEW YORK: GEORGE BRAZILLER, 1972.

GREGOR '92 AND MELINDA ANDRADE

Scholarship Brings Support Full Circle

When Gregor Andrade '92 first saw MIT, he was just shy of his fifth birthday. His father, Gilberto Andrade NUE '78, had come to MIT from their native Brazil for a degree in nuclear engineering. The family returned to the São Paulo region, but Gregor's time in Cambridge had left a deep impression. In 1988, he returned to MIT as an undergraduate.

"For a kid from Brazil, an education from a top American university was very costly at that time. My parents contributed everything they could, and MIT stepped up, very generously, with a scholarship. I'll always remember that."

In 2006, Gregor and his wife, Melinda, gave back to MIT—and today's students—by creating the Andrade Family Scholarship Fund for undergraduates. "It makes me proud that our family was able to create this scholarship," says Melinda. When she and Gregor considered what contributions they might make to change lives, they agreed: "The answer is education."

Gregor has spent his career in finance, but when he came to MIT, he was planning to

become a physicist. Before long, however, he was drawn to economics and finance, inspired by then-MIT faculty member and economist Paul Krugman PhD '77 and finance scholar Andrew Lo, the Charles E. and Susan T. Harris Professor at the MIT Sloan School of Management.

While at the Institute, Gregor also treasured MIT's international community, which was "very welcoming, full of different languages and cultures." He was proud to row for the men's crew team, coached by Stu Schmill '86, now dean of Admissions and Student Financial Services. Crew is "the ultimate team sport," Gregor says, because everyone must be "perfectly in sync, with the same energy and direction."

After MIT, Gregor headed to the University of Chicago for a PhD in finance. He met Melinda Ewing through the university's executive MBA program in Barcelona, Spain. At the time, Melinda was managing a busy career in Prague, where she ran her own public relations firm. After navigating a cross-Atlantic relationship—no easy feat, Melinda recalls, in the days of "dial-up email"—

"My parents contributed everything they could, and MIT stepped up, very generously, with a scholarship," Gregor says. "I'll always remember that."

the pair returned stateside and began a new chapter, in Cambridge.

After teaching at Harvard Business School, Gregor transitioned to AQR Capital Management, an investment firm that utilizes technology, data, and behavioral finance to serve a global clientele. "AQR was a great fit for me, because their investing is research driven, which was natural to me because of my training. And we engage with clients in a very educational way." Today, Gregor is global head of institutional business development at AQR. The Andrades reside in New Canaan, CT, with their 15-year-old twin daughters and 13-year-old son.

"We now, officially, have three teenagers," Gregor says. "And we're still sane!" Melinda adds, laughing. Asked to describe their parents, the kids give Gregor and Melinda loving reviews: Dad is "intelligent, objective, humble, and funny," and Mom is "bright, curious, nurturing, and *very* organized."

In April 2019, Gregor and Melinda were delighted to attend the annual scholarship and UROP brunch at MIT celebrating scholarship donors and recipients. "The students were fascinating," says Melinda, adding that the event made them both feel even more connected to MIT.

Gregor adds that while many types of gifts to MIT are important, directing his contributions to scholarships has made giving back feel "even more powerful." As the world faces complex challenges like Covid-19, he believes the strengths of MIT, and its students, are more relevant than ever. To solve complex human problems, he says, we must "be guided by science, let research speak," and continually search for truth. "Those are the values that MIT has always stood for." —Kris Willcox



NEIL WEBBER '83

Philanthropy Centered on Access to Education

Neil Webber '83 has been focused on philanthropy for much of his career. The cofounder, vice president of engineering, and chief technology officer at Vignette Corporation, Webber formed the Webber Family Foundation after Vignette went public in 1999; the foundation, which he chairs, targets the educational needs of lower-income youth. In addition, Webber is board chair of the national Breakthrough Collaborative, a nonprofit focused on increasing education equity. Its programs are designed not only to ensure that more underrepresented students can graduate from high school and attend and finish college but also to develop and enhance diverse teacher pipelines and improve the education system itself.

“Given my philanthropic goals, I was naturally interested in scholarships when I first had the opportunity to support MIT,” says Webber, who previously made a transformative gift to establish the Neil Webber Scholarship Fund at the Institute. “I particularly appreciate MIT’s need-blind admission process, and I felt confident that the funds would be used to assist talented, deserving students.”

In more than two decades of working in philanthropy, including a recent stint as chair of Breakthrough Central Texas, Webber has also come to appreciate the impact of unrestricted giving. When he had an opportunity to reengage with MIT through the Campaign for a Better World, he looked for departments or programs that both aligned with his priorities and could make the most of unrestricted support. He landed on the MIT Quest for Intelligence, which works to make artificial intelligence more broadly accessible, and the MIT School Effectiveness and Inequality Initiative (SEII) within the Department of Economics.

“Causal impact results of education research can be difficult to determine from the data we can currently collect on specific programs,” Webber says. “SEII is doing really great work in this field.” He’s particularly interested in the research that Parag Pathak, the Jane Berkowitz Carlton and Dennis William Carlton Professor of Microeconomics at MIT and founder of SEII, is doing on the effectiveness of charter schools. Pathak, who won the John Bates Clark Medal in 2018 for his research on the impacts of educational policies, is undertaking work that has the potential to provide valuable insight on which educational environments can offer underserved students the best opportunities for success.



Supporting the MIT Quest was similarly appealing to Webber because of its focus on developing innovative learning environments. “Postsecondary education is undergoing many changes,” he says. “We need to adapt and redefine what a valuable college experience means now and in the future.”

Webber chose to give through a Donor-Advised Fund (DAF), a relatively new option at MIT that he credits with giving him the time to research and learn about the areas of the Institute where his gift could have the most impact. “The DAF mechanism allowed me to schedule the gift the way I wanted to, while deferring the decision on exactly where the money should be applied. It was a great vehicle for making a contribution to the Campaign, and MIT made it a smooth process,” he says.

Webber says his overarching reason for supporting MIT is the knowledge that the Institute is doing important work and is open to engaging those who can aid its progress. “Access to education for the students who have the intellectual ability to further that work, along with the motivation to reach their full potential, is the foundation that makes MIT the innovative leader that it is,” he says. —Amy Mackin

PHOTO: MATTHEW BUSCH

Better World Virtual Events Highlight Science, Health, Sustainability

SCIENCE AND DISCOVERY

Canada

Tuesday, November 17, 2020

INNOVATIONS IN HUMAN HEALTH

Mid-Atlantic (US)

(Delaware, Maryland, New Jersey, Pennsylvania, Virginia, Washington, DC)

Thursday, February 18, 2021

With a series of dynamic virtual events, the MIT Campaign for a Better World continues to spotlight MIT alumni, students, faculty, and donors who are working to ensure a positive future for all.

TOWARD A SUSTAINABLE FUTURE

Four Corners (US)

(Arizona, Colorado, New Mexico, Utah)

Tuesday, March 16, 2021



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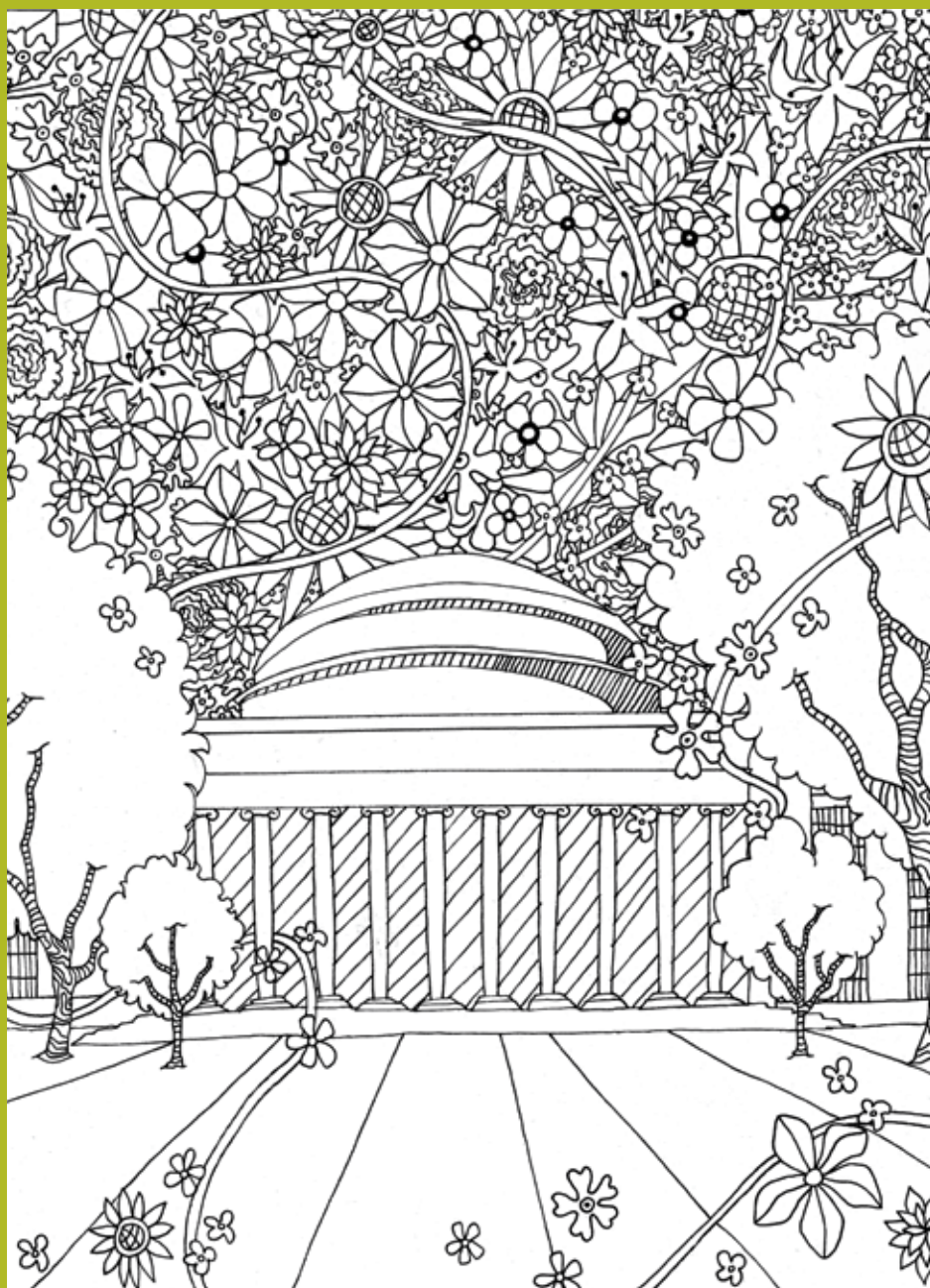
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A FLORAL TRIBUTE

Patricia Gao '21 created this artwork for the official MIT MindHandHeart coloring book, a collection of student and staff artwork showcasing MIT's vibrant community spirit. The coloring book was developed this spring by MindHandHeart, an MIT coalition working to make the Institute more welcoming, healthy, and inclusive. "Making art is helping me get through the pandemic, so I hope that my page can help others cope too," says Gao.

(➔)

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