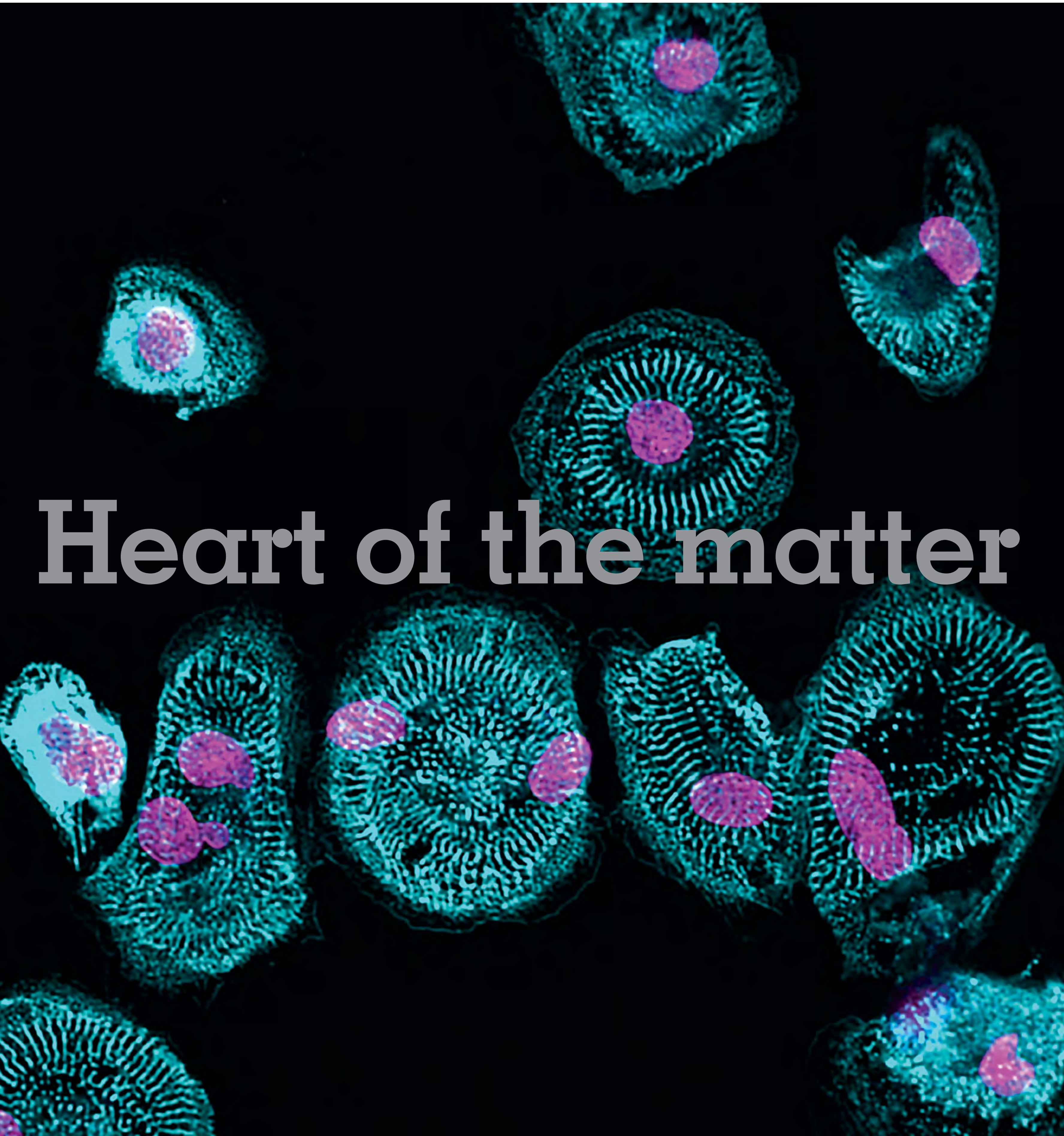
Science AT MIT

Spring 2021 **Published twice yearly**



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Spring 2021 | **Published twice yearly**

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Engineering mature cardiac muscle from human stem cells has tremendous potential for regenerative medicine and as a system for drug and toxicology screening. Pictured is a high-resolution structure of sarcomere organization of a mature cardiac muscle. Additional research is needed to achieve the functional and structural characteristics of mature muscle from stem cells. Image: Boyer Lab

SCHOOL OF SCIENCE
Massachusetts Institute of Technology

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Letter from the Dean

My fellow alumni and friends,

I write to you at the turn of the season and the blooming of hope. Across the state, the country, and the world, we are seeing an uptick in vaccinations that will pull us out of this pandemic and into a safer, and hopefully more peaceful, time. We are on the precipice of a new era, not only in the ways we live our lives post-Covid, but also in how we might see the life sciences expand and evolve.

The speed at which the first vaccines were developed and made available to the public is nothing short of a triumph for the life sciences. From sequencing the virus, to conducting clinical trials, to securing FDA authorization, to initial distribution, the mRNA vaccines for Covid came to fruition in under a year. Truly incredible!

The mRNA vaccine technology is based on decades-long research and the discovery of mRNA and split genes — discoveries made by the MIT School of Science's own Phil Sharp. In our feature article, Professor Sharp explains how curiosity-driven research out of MIT's Cancer Center in the 1970s would lead to a Nobel Prize for him in the 1990s and a vaccine for the world today.

At MIT, this fundamental research in the life sciences continues, and its connections with other areas, such as brain and cognitive sciences, are ever-expanding. In a profile on page 10, you can learn more about doctoral student Omar Rutledge, a combat veteran examining the ways in which post-traumatic stress disorder and the effects of isolation may physically alter connections in the brain. On page 7, you can read about Professor Laurie Boyer's investigations that have shown that having three copies of chromosome 21, or Down syndrome, has profound effects not only on neuronal connections but on cardiac tissue as well.

As Dyann Wirth '78 states: "There has never been a more important time to support the life sciences. This is a time of amazing discovery, enormous opportunity and great challenges." You can read more about Dyann, a leading biologist in the study of malaria, and her challenge to support science scholarship in this year's 24-Hour Challenge. Along with donors Priscilla King Gray and Glenda Mattes, Dyann pledged to help support our students and faculty, including our cross-disciplinary research in biology and through the Aging Brain Initiative.

But biology and brain and cognitive sciences are only two of the many areas within in our scientific enterprise. On page 12, you can read about my physics colleague Lindley Winslow and her explorations of neutrinos and the world of particle physics.

On page 22, you can also learn about Frank Wilczek's career-long exploration into the fundamental theories of physics in his recently published book and Richard Binzel's contributions to the New Horizons mission to Pluto.

At our March virtual event, MIT Better World–Sustainability, David McGee and Jeremiah Johnson, in the Departments of EAPS and Chemistry, respectively, presented recent research from their labs. You can watch the recorded sessions about paleoclimates and plastic chemistry at your leisure. (An overview of the event and details on how to watch are found on page 16.)

This spring, four of our faculty (out of only 20 named nationally) received awards from the National Academy of Sciences (NAS) for extraordinary scientific achievements in fields spanning the physical, biological, social, and medical sciences. Four additional faculty were recently elected to the NAS, three in mathematics and one in chemistry. You can read more about their research on page 17.

While research proceeds apace despite this year's multiple challenges, we are also engaged in community-wide conversations and sweeping action on issues of belonging, dignity, and justice in the school and across MIT. If you haven't yet read the Institute's Diversity, Equity, and Inclusion action plan, please visit: deiactionplan.mit.edu.

We in the School of Science are in the process of hiring an assistant dean for diversity. This position will be one of six at the Institute — one in each school and the College of Computing — and will report directly to me with a dotted line to the Institute Community and Equity Office. Having a dedicated professional guiding our efforts to create a more inclusive MIT will be key to making the better world we all want to see here at MIT and beyond.

With my very best wishes and hope for the future,

Dean Nergis Mavalvala PhD '97

Long arc of science enables mRNA vaccines for Covid-19

Curiosity-driven basic science in the 1970s laid the groundwork for today's leading vaccines against the novel coronavirus

Julia C. Keller | School of Science

Phillip A. Sharp, Institute Professor and Professor of Biology, and member of the Koch Institute for Integrative Cancer Research

Some of the most promising vaccines developed to combat Covid-19 rely on messenger RNA (mRNA) — a template that cells use to carry genetic instructions for producing proteins. The mRNA vaccines take advantage of this cellular process to make proteins that then trigger an immune response that targets SARS-CoV-2, the virus that causes Covid-19.

Compared to other types of vaccines, recently developed technologies allow mRNA vaccines to be rapidly created and deployed on a large-scale — crucial aspects in the fight against Covid-19. Within the year since the identification and sequencing of the SARS-CoV-2 virus, companies such as Pfizer and Moderna have developed mRNA vaccines and run large-scale trials in the race to have a vaccine approved by the U.S. Food and Drug Administration — a feat unheard of with traditional vaccines using live attenuated or inactive viruses. These vaccines appear to have a greater than 90 percent efficacy in protecting against infection.

The fact that these vaccines could be rapidly developed rests on more than four decades of study of mRNA. This success story begins with Institute Professor Phillip A. Sharp's discovery of split genes and spliced RNA that took place at MIT in the 1970s — a discovery that would earn him the 1993 Nobel Prize in Physiology or Medicine.

> "I liken RNA splicing to discovering the Rosetta Stone. We understood how the same letters of the alphabet could be written and rewritten to form new words, new meaning, and new languages."

Sharp, a professor within the Department of Biology and member of the Koch Institute for Integrative Cancer Research at MIT, commented on the long arc of scientific research that has led to this groundbreaking, rapid vaccine development — and looked ahead to what the future might hold for mRNA technology.

Q: Professor Sharp, take us back to the fifth floor of the MIT Center for Cancer Research in the 1970s. Were you and your colleagues thinking about vaccines when you studied viruses that caused cancer?

A: Not RNA vaccines! There was a hope in the '70s that viruses were the cause of many cancers and could possibly be treated by conventional vaccination with inactivated virus. This is not the case, except for a few cancers such as HPV causing cervical cancer.

Also, not all groups at the MIT Center for Cancer Research (CCR) focused directly on cancer. We knew so little about the causes of cancer that Professor Salvador Luria, director of the CCR, recruited faculty to study cells and cancer at the most fundamental level. The center's three focuses were virus and genetics, cell biology, and immunology. These were great choices.

Our research was initially funded by the American Cancer Society, and we later received federal funding from the National Cancer Institute, part of the National Institutes of Health and the National Science Foundation — as well as support from MIT through the CCR, of course.

At Cold Spring Harbor Laboratory in collaboration with colleagues, we had mapped the parts of the adenovirus genome responsible for tumor development. While doing so, I became intrigued by the report that adenovirus RNA in the nucleus was longer than the RNA found outside the nucleus in the cytoplasm where the messenger RNA was being translated into proteins. Other scientists had also described longer-than-expected nuclear RNA from cellular genes, and this seemed to be a fundamental puzzle to solve.

Susan Berget, a postdoc in my lab, and Claire Moore, a technician who ran MIT's electron microscopy facility for the cancer center and would later be a postdoc in my lab, were instrumental in designing the experiments that would lead to the iconic electron micrograph that was the key to unlocking the mystery of this "heterogeneous" nuclear RNA. Since those days, Sue and Claire have had successful careers as professors at Baylor College of Medicine and Tufts Medical School, respectively.

The micrograph showed loops that would later be called "introns" — unnecessary extra material in between the relevant segments of mRNA, or "exons." These exons would be joined together, or spliced, to create the final, shorter message for the translation to proteins in the cytoplasm of the cell.

This data was first presented at the Cancer Center fifth floor group meeting that included Bob Weinberg, David Baltimore, David Housman, and Nancy Hopkins. Their comments, particularly those of David Baltimore, were catalysts in our discovery. Our curiosity to understand this basic cellular mechanism drove us to learn more, to design the experiments that could elucidate the RNA splicing process. The collaborative environment of the MIT Cancer Center allowed us to share ideas and push each other to see problems in a new way.

Q: Your discovery of RNA splicing was a turning point, opening up new avenues that led to new applications. What did this foundation allow you to do that you couldn't do before?

Members of the MIT Center for Cancer Research (Robert Weinberg, second row from bottom, far left; Susan Berget, third row from bottom, third from left; Claire Moore, back row, fourth from left; Philip Sharp, back Row, far right).
Photo: Robert Weinberg

A: Our discovery in 1977 occurred just as biotechnology appeared with the objective of introducing complex human proteins as therapeutic agents, for example interferons and antibodies. Engineering genes to express these proteins in industrial tanks was dependent on this discovery of gene structure. The same is true of the RNA vaccines for Covid-19: By harnessing new technology for synthesis of RNA, researchers have developed vaccines whose chemical structure mimics that of cytoplasmic mRNA.

In the early 1980s, following isolation of many human mutant disease genes, we recognized that about one-fifth of these were defective for accurate RNA splicing. Further, we also found that different isoforms of mRNAs encoding different proteins can be generated from a single gene. This is "alternative RNA splicing" and may explain the puzzle that humans have fewer genes — 21,000 to 23,000 — than many less complex organisms, but these genes are expressed in more complex protein isoforms. This is just speculation, but there are so many things about biology yet to be discovered.

I liken RNA splicing to discovering the Rosetta Stone. We understood how the same letters of the alphabet could be written and rewritten to form new words, new meaning, and new languages. The new "language" of mRNA vaccines can be developed in a laboratory using a DNA template and readily available materials. Knowing the genetic code of the SARS-CoV-2 is the first step in generating the mRNA vaccine. The effective delivery of vaccines into the body based on our fundamental understanding of mRNA took decades more work and ingenuity to figure out how to evade other cellular mechanisms perfected over hundreds of millions of years of evolution to destroy foreign genetic material.

Q: Looking ahead 40 more years, where do you think mRNA technology might be?

A: In the future, mRNA vaccine technology may allow for one vaccine to target multiple diseases. We could also create personalized vaccines based on individuals' genomes.

Messenger RNA vaccines have several benefits compared to other types of vaccines, including the use of noninfectious elements and shorter manufacturing times. The process can be scaled up, making vaccine development faster than traditional methods. RNA vaccines can also be moved rapidly into clinical trials, which is critical for the next pandemic.

It is impossible to predict the future of RNA therapies, such as the new vaccines, but there are some signs that new advancements could happen very quickly. A few years ago, the first RNA-based therapy was approved for treatment of lethal genetic disease. This treatment was designed through the discovery of RNA interference. Messenger RNA-based therapies will also likely be used to treat genetic diseases, vaccinate against cancer, and generate transplantable organs. It is another tool at the forefront of modern medical care.

But keep in mind that all mRNAs in human cells are encoded by only 2 percent of the total genome sequence. Most of the other 98 percent is transcribed into cellular RNAs whose activities remain to be discovered. There could be many future RNA-based therapies.

Queen of hearts

Professor of Biology Laurie Boyer studies cardiac development, and how we might be able to mend broken hearts

Alison Gold | School of Science

Amphibians and humans differ in many ways, but Professor of Biology and Biological Engineering Laurie Boyer is particularly interested in one of those differences. Certain types of amphibians and fish can regenerate and heal their hearts after an injury. However, human adults who have experienced trauma to the heart, such as in the case of a heart attack or exposure to certain medications, are unable to repair the damage. Often, the injured heart ends up with scar tissue that can lead to heart failure.

Recent research in this area now indicates that mice, and even humans, have some capacity for cardiac repair for a short period after birth. But after even just a few days of age, that ability starts to shut off. "The heart has very limited ability to repair itself in response to injury, disease, or aging," Boyer says.

Alexander Auld, a postdoc in the Boyer Lab, studies the key cellular mechanisms that lead heart cells to mature and lose regenerative potential. Specifically, he's interested in understanding how cardiomyocytes, the heart cells responsible for pumping blood, develop an ability to contract and relax repeatedly. Auld tests the function of proteins that serve as signals to assemble the cardiac muscle structure after birth. The assembly of these structures coincides with the loss of regenerative ability.

"I'm trying to piece together: what are the different mechanisms that push cardiomyocytes to assemble their contractile apparatus and to stop dividing?" Auld says. "Solving this puzzle may have potential to stimulate regeneration in the adult heart muscle."

"The holy grail of regenerative biology would be to stimulate your own heart cells to replenish themselves," says Boyer, who joined the MIT faculty in 2007. "Before this approach is possible, we need to achieve a deep understanding of the fundamental processes that drive heart development."

Boyer's lab studies how many different signals and genes interact to affect heart development. The work will enable a better understanding of how faulty regulation can lead to disease, and may also enable new therapies for people suffering from a variety of heart conditions.

Laurie Boyer, Professor of Biology and Biological Engineering. Photo: Alison Gold

Critical connections

Recently, Boyer's lab has been studying heart development in people with Trisomy 21, or Down syndrome. Every year, 6,000 babies born in the United States have Down syndrome. Around half have heart defects. The most common heart defect in babies with Down syndrome is a hole in the heart's center, called an atrioventricular septal defect. It is often repaired with surgery, but the repair can cause scar tissue and cardiovascular complications.

Somatic cells, as opposed to sex cells used for reproduction, are those that compose an organism's body. Most people have 46 chromosomes, arranged in 23 pairs, in their body's somatic cells. In 95 percent of cases, Down syndrome results when a person has three copies of chromosome 21 instead of two — a total of 47 chromosomes per cell. It's an example of aneuploidy, when a cell has an abnormal number of chromosomes. Cellular attempts to adapt to the extra chromosome can cause stress on the body's cells, including those of the heart.

MIT's Alana Down Syndrome Center (ADSC) brings together biologists, neuroscientists, engineers, and other experts to increase knowledge about Down syndrome. ADSC launched in early 2019, led by Angelika Amon, a professor of biology, and a member of the Koch Institute for Integrative Cancer Research, along with co-director Li-Huei Tsai, Picower Professor and director of the Picower Institute for Learning and Memory. Amon died at age 53 in 2020 after a battle with ovarian cancer. At MIT, Amon had studied the effects of aneuploidy on cells.

"In my many wonderful scientific and personal discussions with Angelika, who was a beacon of inspiration to me, it

Alexander Auld is a postdoc in the Boyer Lab, where he studies how heart cells assemble during cardiac development. Photo: Alison Gold

became clear that studying Trisomy 21 in the context of heart development could ultimately improve the lives of these individuals," Boyer says.

In the Boyer Lab, Professor Laurie Boyer and postdoc Alex Auld study how many different signals and genes interact to affect heart development. The work will enable a better understanding of how faulty regulation can lead to disease, and may also enable new therapies for people suffering from a variety of heart conditions. Photo: Alison Gold

Change of heart

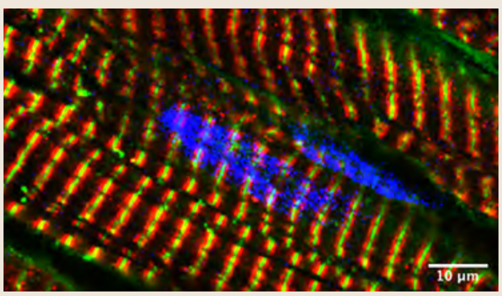
To conduct their research, Boyer's group uses human induced pluripotent cells (hiPSCs), obtained through somatic cell reprogramming. The revolutionary technique was developed by Sir John B. Gurdon and Shinya Yamanaka, who in 2012 won the Nobel Prize in Physiology or Medicine for their work. Reprogramming works by converting specialized, mature somatic cells with one particular function into specialized, mature, cells with a different function.

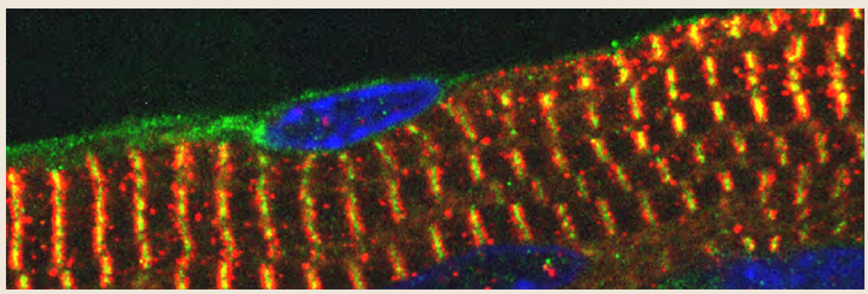
Boyer's lab uses hiPSCs from human adults with Down syndrome and converts them into cardiomyocytes through somatic cell reprogramming. Then, they compare those cardiomyocytes with reprogrammed cells from individuals who do not have Down syndrome. This work helps them deduce why the extra chromosome in people with Down syndrome may cause congenital heart defects.

"We can now begin to pinpoint the faulty signals and genes in Trisomy 21 cardiac cells that affect heart development," Boyer says. "And with that same idea, we can also discover how we might actually be able to ameliorate or fix these defects."

With this technique, the team can track how aspects of specific patients' cell development correlate with their clinical presentations. The ability to analyze patient-specific cells also has implications for personalized medicine, Boyer says. For instance, a patient's skin or blood cells — which are more easily obtained — could be converted into a highly specialized mature cell, like a cardiac muscle cell, and tested for its response to drugs that could possibly cause damage to the heart before they reach the clinic. This

> “The holy grail of regenerative biology would be to stimulate your own heart cells to replenish themselves.”





High-resolution structure of the sarcomere organization of a mature cardiac muscle. Additional research is needed to achieve the functional and structural characteristics of mature muscle from stem cells. Images: Boyer Lab

process can also be used to screen for new therapies that can improve the outcome for heart failure patients.

Boyer presented the group’s research on Down syndrome at the New England Down Syndrome Symposium, co-organized in November by MIT, ADSC, Massachusetts Down Syndrome Congress, and LuMind IDSC Foundation.

Heart of the operation

Boyer’s lab employs students at the undergraduate, graduate, and postdoc levels from engineering, life sciences, and computer sciences — each of whom, Boyer says, brings unique expertise and value to the team.

“It’s important for me to have a lab where everyone feels welcome, and that they feel that they can contribute to these fundamental discoveries,” Boyer says.

The Boyer Lab often works with scholars across disciplines at MIT. “It’s really great,” Auld says. “You can investigate a problem using multiple tools and perspectives.” One project, in partnership with George Barbastathis, a professor in Mechanical Engineering, uses image-based machine learning to understand structural differences within cardiomyocytes when the proteins that signal cells to develop have been manipulated. Auld generates high-resolution images that the machine learning algorithms can analyze.

Another project, in collaboration with Ed Boyden, a professor in the Department of Biological Engineering as well as the McGovern Institute for Brain Research, involves the development of new technologies that allow high throughput imaging of cardiac cells. The cross-pollination across departments and areas of expertise at MIT, Boyer says, often has her feeling like “a kid in a candy shop.”

“That our work could ultimately impact human health is very fulfilling for me, and the ability to use our scientific discoveries to improve medical outcomes is an important direction of my lab,” Boyer says. “Given the enormous talent at MIT and the excitement and willingness of everyone here to work together, we have an unprecedented opportunity to solve important problems that can make a difference in people’s lives.”

This work was made possible by awards from MIT: the Frontier award from the Koch Institute, John W. Jarve (1978) Seed Fund for Science Innovation, an award from the MIT Center for Environmental Health Sciences; and from the National Heart, Lung, and Blood Institute at the National Institutes of Health.

Embattled brain

Combat veteran and PhD candidate Omar Rutledge drives research on PTSD

Laura Carter | School of Science

A car backfires in a parking lot. An army veteran, recently returned from a combat zone, might duck and cover. They know that they are no longer in an active war zone, but they were trained to react before thinking, an ability that meant life over death at one point in their life.

That training is so ingrained it has physically altered the way their brain works, weakening the connection between the amygdala, which is responsible for emotions like fear, and the prefrontal cortex, which regulates or controls these emotional responses.

How post-traumatic stress disorder (PTSD) — a mental condition caused by a severe psychological shock that leaves persistent symptoms such as anxiety, depression, sleep disturbance, and even physical pain — affects the brain and its functions is the focus of graduate student Omar Rutledge's research in the Department of Brain and Cognitive Sciences. He is uniquely situated to study this topic, having been deployed to Iraq himself from March 2003 to July 2004, resulting in firsthand experience with PTSD.

Omar Rutledge served as a US Army Infantryman in the 1st Armored and 25th Infantry Divisions. He was deployed in support of Operation Iraqi Freedom from March 2003 to July 2004. Photo courtesy of Rutledge.

Coronavirus impedes and inspires

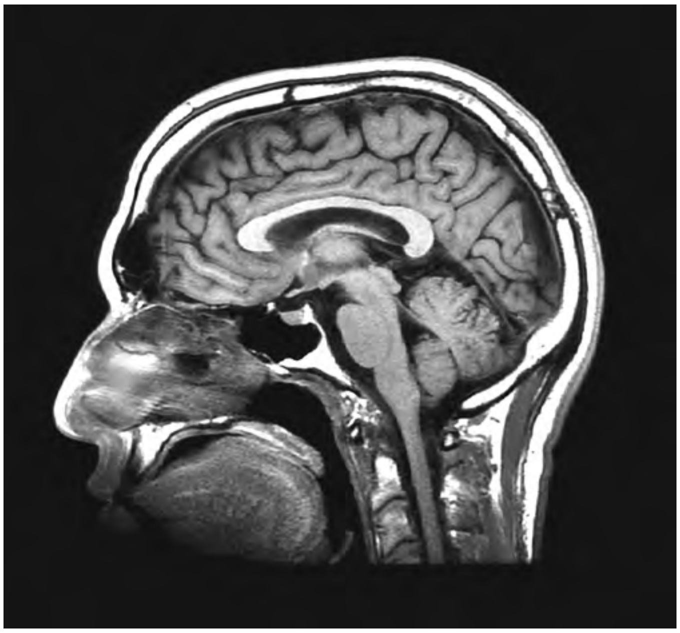
Rutledge, a third-year PhD candidate, is looking at ways to specifically prevent situations in which acting on a triggering event before thinking is no longer a useful survival skill. For example, when our brains sense fear, they send signals that may temporarily alter our skin to conduct electricity more easily — think of the infamous polygraph, or lie detector test. In the future, a device like a watch could measure this skin conductance and send an alert allowing the wearer to prioritize managing their response to the triggering event, such as breathing more slowly instead of ducking behind an object, effectively retraining the brain to be less responsive to triggering events.

Though Covid-19 has put some aspects of this research on hold, the pandemic has inspired another project based on the need for social distancing. Rutledge wants to test whether the loneliness caused by physical distancing protocols can induce physical or chemical changes in the brain similar to changes affiliated with PTSD.

Imagine walking down the street at night. Someone else approaches from the other direction. If someone is accompanying you, that new person is likely not evaluated as a threat. When you are by yourself? "Most likely," he asserts. The longer humans are alone, the more other people become perceived as threats.

"There's this hypervigilance that occurs in loneliness, and there's also something very similar that occurs in PTSD — a heightened awareness of potential threats. The combination of the two may lead to more adverse reactions in people with PTSD," says Rutledge, who is the 2020–2021 recipient of McGovern Institute for Brain Research's Michael Ferrara graduate fellowship provided by the Poitras Center for Psychiatric Disorders Research, a fellowship made possible by the many friends and family of Michael Ferrara.

Work has already been done at MIT to investigate short-term loneliness' effect on the brain on a social level. In his future research plans, Rutledge said he hopes to explore whether and how chronic loneliness causes cognitive impairment. From there, further investigation could determine if loneliness has a deeper impact on veterans who have PTSD.



Omar Rutledge uses MRI images, such as this one of a veteran with PTSD, to research the connection between trauma and the mind. Image courtesy of Rutledge.

From war zone to campus

After making the seemingly impossible transition back from Iraq into civilian life in the United States, Rutledge turned to psychology to learn more about what he was experiencing, earning a bachelor's degree in psychology from the University of Alaska at Fairbanks in 2012. To his dismay, he found little had been done to truly understand the nature of combat-associated PTSD.

For a broken bone, a doctor diagnoses the problem via X-ray, develops a plan to correct the issue, employs the necessary steps for repair, and then evaluates if the treatment succeeded. There is no analogous process for mental disorders.

"We can't scan your individual brain and come up with a list of things that we can do to improve your situation. There's nothing like that," Rutledge says. "But that doesn't mean we can't try. That's something that's been on my mind since the very beginning." He went on to earn a master's degree in biomedical imaging at the University of California at San Francisco, which he completed in 2015.

For his next step, he planned to pursue a doctorate in a neuroscience program in order to go beyond understanding what is physically happening in the brain and begin to tie the brain to the mind using various tools. But he never imagined being able to do this work at MIT.

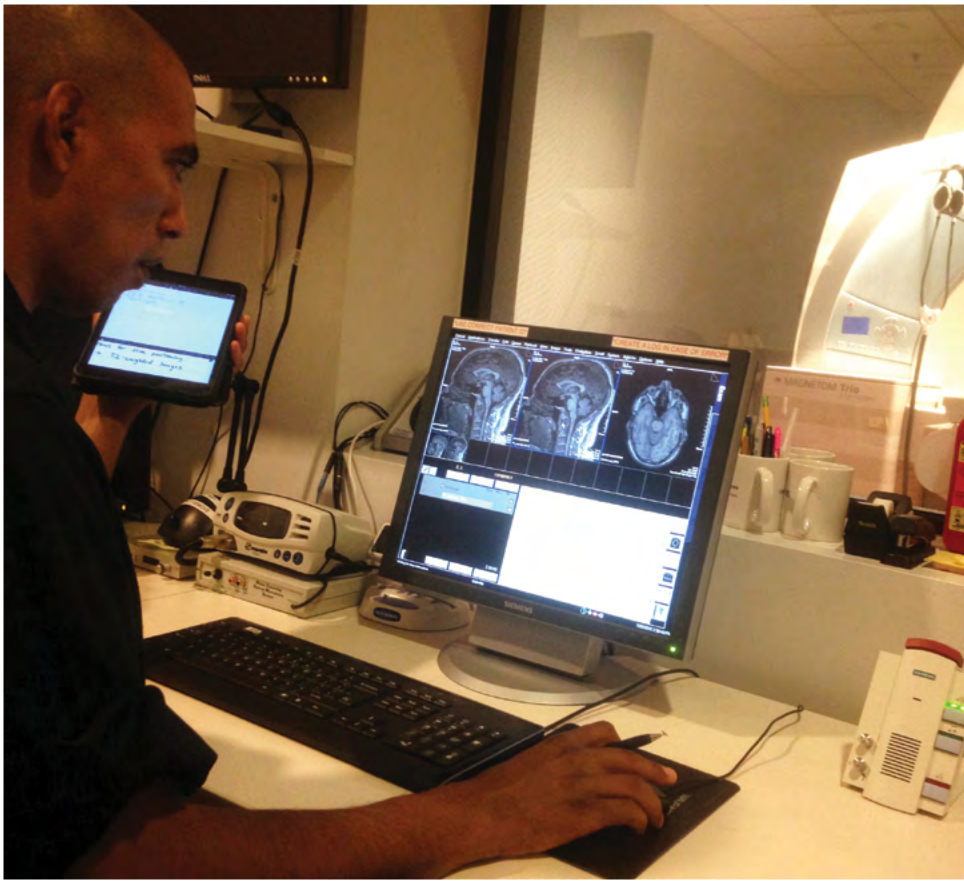
A new kind of mission

Rutledge's firsthand combat experience has enabled studies into PTSD with veterans to go deeper despite dredging up painful memories. "Even though I may be reopening my own wounds by listening to others share their stories, if I can help other veterans heal, I feel it's worth it. In the process, it makes me a little bit stronger as well," he says.

Last year, Rutledge received a James S. (1972) and Muguette Alder Fellowship, which is awarded annually to a graduate student in Brain and Cognitive Sciences working on bipolar disorder and related diseases or, more broadly, mental illness, and is sponsored by a gift from Jim and Muguette Alder.

With Rutledge now a part of the "Gab Lab," John Gabrieli, the Grover Hermann Professor of Health Sciences and Technology, Cognitive Neuroscience Professor in the Department of Brain and Cognitive Sciences, and member of McGovern Institute, has someone who can advocate for PTSD research at MIT.

"I feel like it has been a mission of mine to do this kind of work," explains Rutledge. "In the world of PTSD research, I look to my left and to my right, and I don't see other veterans, certainly not a former infantry guy. If there are so few of us in this space, I feel like I have an obligation to make a difference for all who suffer from the traumatic experiences of war."



By studying the details of MRI scans such as these, Omar Rutledge studies how PTSD affects the brain. Photo: Zach Skiles

Measuring the invisible

Particle physicist Lindley Winslow seeks the universe's smallest particles for answers to its biggest questions

Jennifer Chu | MIT News Office

When she entered the field of particle physics in the early 2000s, Lindley Winslow was swept into the center of a massive experiment to measure the invisible.

Scientists were finalizing the Kamioka Liquid Scintillator Antineutrino Detector, or KamLAND, a building-sized particle detector built within a cavernous mine deep inside the Japanese Alps. The experiment was designed to detect neutrinos — subatomic particles that pass by the billions through ordinary matter.

Neutrinos are produced anywhere particles interact and decay, from the Big Bang to the death of stars in supernovae. They rarely interact with matter and are therefore pristine messengers from the environments that create them.

By 2000, scientists had observed neutrinos from various sources, including the sun, and hypothesized that the particles were morphing into different "flavors" by oscillating. KamLAND was designed to observe this oscillation, as a function of distance and energy, in neutrinos generated by Japan's nearby nuclear reactors.

Winslow joined the KamLAND effort the summer before graduate school and spent months in Japan, helping to prepare the detector for operation and then collecting data.

"I learned to drive a manual transmission on reinforced land cruisers into the mine, past a waterfall, and down a long tunnel, where we then had to hike up a steep hill to the top of the detector," Winslow says.

Lindley Winslow, Jerrold R. Zacharias Career Development Associate Professor of Physics. Photo: M. Scott Brauer

In 2002, the experiment detected neutrino oscillations for the first time.

"It was one of those moments in science where you know something that no one else in the world does," recalls Winslow, who was part of the scientific collaboration that received the Breakthrough Prize in Fundamental Physics in 2016 for the discovery.

The experience was pivotal in shaping Winslow's career path. In 2020, she received tenure as associate professor of physics at MIT, where she continues to search for neutrinos, with KamLAND and other particle-detecting experiments that she has had a hand in designing.

"I like the challenge of measuring things that are very, very hard to measure," Winslow says. "The motivation comes from trying to discover the smallest building blocks and how they affect the universe we live in."

Measuring the impossible

Winslow grew up in Chadds Ford, Pennsylvania, where she explored the nearby forests and streams, and also learned to ride horses, even riding competitively in high school.

She set her sights west for college, with the intention of studying astronomy, and was accepted to the University of California at Berkeley, where she happily spent the next decade, earning first an undergraduate degree in physics and astronomy, then a master's and PhD in physics.

Midway through college, Winslow learned of particle physics and the large experiments to detect elusive particles. A search for an undergraduate research project introduced her to the Cryogenic Dark Matter Search, or CDMS, an experiment that was run beneath the Stanford University campus. CDMS was designed to detect weakly interacting massive particles, or WIMPS — hypothetical particles that are thought to comprise dark matter — in detectors wrapped in ultrapure copper. For her first research project, Winslow helped analyze copper samples for the experiment's next generation.

"I liked seeing how all these pieces worked together, from sourcing the copper to figuring out how to build an experiment to basically measure the impossible," Winslow says.

Her later work with KamLAND, facilitated by her quantum mechanics professor and eventual thesis advisor, further inspired her to design experiments to search for neutrinos and other fundamental particles.

Little particles, big questions

After completing her PhD, Winslow took a postdoc position with Janet Conrad, professor of physics at MIT. In Conrad's group, Winslow had freedom to explore ideas beyond the lab's primary projects. One day, after watching a video about nanocrystals, Conrad wondered whether the atomic-scale materials might be useful in particle detection.

"I remember her saying, 'These nanocrystals are really cool. What can we do with them? Go!' And I went and thought about it," Winslow says.

She soon came back with an idea: What if nanocrystals made from interesting isotopes could be dissolved in liquid scintillator to also realize more sensitive neutrino detection? Conrad thought it was a good idea and helped Winslow seek out grants to get the project going.

In 2010, Winslow was awarded the L'Oréal for Women in Science Fellowship and a grant that she put toward the nanocrystal experiment, which she named NuDot, for the quantum dots (a type of nanocrystal) that she planned to work into a detector. When she finished her postdoc, she accepted a faculty position at the University of California at Los Angeles, where she continued laying plans for NuDot.

A cold bargain

Winslow spent two years at UCLA, during a time when the search for neutrinos circled around a new target: neutrinoless double-beta decay, a hypothetical process that, if observed, would prove that the neutrino is also its own antiparticle, which would help to explain why the universe has more matter than antimatter.

At MIT, physics professor and department head Peter Fisher was looking to hire someone to explore double-beta decay. He offered the job to Winslow, who negotiated in return.

"I told him what I wanted was a dilution refrigerator," Winslow recalls. "The base price for one these is not small, and it's asking a lot in particle physics. But he was like, 'done!'"

Winslow joined the MIT faculty in 2015, setting her lab up with a new dilution refrigerator that would allow her to cool macroscopic crystals to millikelvin temperatures to

"That's all part of my group's vision ... building big experiments that might detect little particles, to answer big questions."

look for heat signatures from double-beta decay and other interesting particles. Today she is continuing to work on NuDot and the new generation of KamLAND, and is also a key member of CUORE, a massive underground experiment in Italy with a much larger dilution refrigerator, designed to observe neutrinoless double-beta decay.

Winslow has also made her mark on Hollywood. In 2016, while settling in at MIT, a colleague at UCLA recommended her as a consultant to the remake of the film "Ghostbusters." The set design department was looking for ideas for how to stage the lab of one of the movie's characters, a particle physicist. "I had just inherited a lab with a huge amount of junk that needed to be cleared out — gigantic crates filled with old scientific equipment, some of which had started to rust," Winslow says. "[The producers] came to my lab and said, 'This is perfect!' And in the end it was a really fun collaboration."

In 2018, her work took a surprising turn when she was approached by theorist Benjamin Safdi, then at MIT, who with MIT physicist Jesse Thaler and former graduate student Yonatan Kahn PhD '15 had devised a thought experiment named ABRACADABRA, to detect another hypothetical particle, the axion, by simulating a magnetar — a type of neutron star with intense magnetic fields that should make any interacting axions briefly detectable. Safdi heard of Winslow's refrigerator and wondered whether she could engineer a detector inside it to test the idea.

"It was an example of the wonderfulness that is MIT," recalls Winslow, who jumped at the opportunity to design an entirely new experiment. In its first successful run, the ABRACADABRA detector reported no evidence of axions. The team is now designing larger versions, with greater sensitivity, to add to Winslow's stable of growing detectors.

"That's all part of my group's vision for the next 25 years: building big experiments that might detect little particles, to answer big questions," Winslow says.

Challenge accepted

During 24-Hour Challenge, record giving puts School of Science on sure footing

Julia C. Keller | School of Science

Every year, MIT challenges its alumni and friends to support its educational programs and research enterprise by giving during a 24-hour window. This year, friends and alumni of the School of Science stepped up to the challenge and put the school second overall in fundraising for the March 11 effort.

With a record number of donors, MIT's 24-Hour Challenge raised nearly $3.39 million to support the work of students, faculty, and staff across the Institute. For the School of Science, the donations went to support fellowships for our students, innovation in research and teaching, and the school's flagship initiative researching healthy aging of the brain.

Great challenges, enormous opportunity

Dyann Wirth PhD '78 served as this year's 24-Hour Challenger for the School of Science and set an ambitious goal: 150 donors would unlock her first gift of $50,000; and if an additional 150 joined the Challenge, she'd double her gift.

An expert in the molecular biology of infectious diseases, Wirth knows firsthand the importance of funding to support an active research program in the life sciences.

"Supporting research into infectious diseases such as malaria necessarily means supporting the graduate students who are the heart and the soul of the lab," says Wirth, who is the current chair of the World Health Organization's Malaria Policy Advisory Committee. She is also a member of the Broad Institute of MIT and Harvard and the Richard Pearson Strong Professor of Infectious Diseases at the Harvard University T. H. Chan School of Public Health.

Dyann Wirth PhD '78
Photo courtesy of Wirth.

"An investment in educating the next generation of scientists is crucial to ensuring our health and well-being in the future," says Wirth. "There has never been a more important time to support the life sciences — this is a time of amazing discovery, enormous opportunity, and great challenges."

The first donor threshold was surpassed in the morning of the Challenge and the next 150 donors followed soon thereafter. Putting the numbers over the top was a groundswell of support for the school's Aging Brain Initiative.

Micro challenge, macro need

Today, an estimated 46 million people worldwide — 5.6 million in the United States — suffer from Alzheimer's disease or some other form of dementia. That number is expected to double every 20 years as life expectancy rises and populations continue to age.

Currently, there are no effective therapies and the economic burden of Alzheimer's disease is unsustainable; in the United States alone, care for Alzheimer's patients is estimated to total $1.1 trillion by 2050 with close to 14 million people suffering from Alzheimer's. Despite these statistics, there is still limited federal support for Alzheimer's disease funding. In the current National Institutes of Health budget, $6.4 billion is spent for cancer research annually compared to less than $3 billion for Alzheimer's.

"The tremendous need to address the burdens of the aging brain — memory loss, cognitive decline, and dementia — is what gave rise to an Institute-wide call to action at MIT," says Michael Sipser, co-founder of the Aging Brain Initiative (ABI), MIT's dean of Science from 2014 to 2020, and Donner Professor of Mathematics. Sipser spearheaded the initiative, along with a team of co-founders including Li-Huei Tsai, director of The Picower Institute for Learning and Memory and the Picower Professor of Neuroscience in the Department of Brain and Cognitive Sciences. Tsai and other founding members of the ABI have conducted research into many aspects of neurodegenerative diseases, such as the genetic predispositions for developing the Alzheimer's disease and the molecular and circuit mechanisms underlying disease pathology and memory loss.

Priscilla King Gray (right), and former MIT president Paul Gray (left). Photo courtesy of Priscilla King Gray.

"The strength of MIT's scientists is unparalleled," says Priscilla King Gray, wife of former MIT president Paul Gray and leader of a microchallenge within the larger 24-Hour Challenge for the School of Science. Paul Gray died in 2017 after a long battle with Alzheimer's disease. "The importance of this Challenge is personal for me but pervasive for all of us. Having witnessed the cruel ravages of Alzheimer's take a vast toll on the life of my husband, it is my hope that the funds raised will contribute to finding a cure for this terrible disease."

One of the most significant genetic risk factors for developing Alzheimer's is a gene called APOE4, which is present in nearly half of all patients. A study led by Tsai and co-authored by ABI co-founder Professor Manolis Kellis shows that this gene significantly disrupts brain cells' ability to carry out normal functions. Researchers showed that treating these cells with additional choline, a safe and widely available supplement, could reverse many of these effects.

In other research, Tsai and ABI co-founders Professors Ed Boyden and Emery N. Brown have moved into clinical studies with non-invasive therapies using light and sound to restore the brain's protective functions by reestablishing its gamma wave frequencies at 40Hz.

"MIT scientists are opening the doors to an entirely new direction of brain research. It is a priority to support their efforts," Sipser says of the 40Hz flashes of visible light and sound stimulation developed by Tsai, Boyden, and Brown. This non-invasive, inexpensive potential treatment for neurodegeneration — GENUS, for Gamma ENtrainment Using Sensory stimuli — has shown protection against neurodegeneration, preservation of memory, and improved cognitive performance in animal models and now trials on humans have begun.

"We are uncovering the keys to neurodegenerative diseases on many levels in the brain," says Glenda Mattes, who championed Gray's Challenge on behalf of her late husband Donald Mattes '67, SM '69. "If we could change the life of one person, one partner, one family, what an achievement that would be!"

At the end of day, more than 300 donors gave more than $50,000 for the Aging Brain and another $30,000 to the School of Science with more than 200 donations from alumni and friends.

For her part, Gray says she believes that every step and every donation is on the path to progress. "Paul was an optimist who firmly believed in the power of taking action. If my story spurs someone to give — something, anything — that's one more step toward a cure, and potentially, elimination of Alzheimer's. I'm honoring his memory and protecting the memory of future people like Paul."

To give to the Aging Brain Initiative, please visit: https://picower.mit.edu/about/aging-brain-initiative

To give to the School of Science, please visit: https://giving.mit.edu/explore/schools/science

Don and Glenda Mattes. Photo courtesy of Glenda Mattes.

Degrading pernicious plastics and predicting using past climates

Basic scientific research is required to make significant progress in sustainability and the climate crisis. More research is needed into how climate change will play out at the regional level: In what areas are impacts on water availability, floods, and heat waves going to be most severe; and how large will these impacts be? MIT scientists can use paleoclimate data to ground-truth our understanding of the scale of past rainfall changes.

Certain plastics are durable and heat-resistant but can't be easily recycled or broken down. MIT chemists can now modify these thermoset plastics to retain their mechanical strength and degrade more easily. The approach could be applicable to a range of plastics and other polymers, such as rubber.

At the Better World–Sustainability event on April 16, David McGee and Jeremiah Johnson, professors in the Departments of Earth, Atmospheric and Planetary Sciences and Chemistry, respectively, presented aspects of their research programs that impact the prediction of precipitation and the creation of useful, but less harmful, materials of the future.

To learn more and watch videos of the event, visit:
https://betterworld.mit.edu/events/sustainability/

Associate Professor David McGee
Photo courtesy of McGee.

Professor Jeremiah Johnson
Photo: Justin Knight

Four MIT scientists honored with 2021 National Academy of Sciences awards

Pablo Jarillo-Herrero, Aviv Regev, Susan Solomon, and Feng Zhang are the recipients of distinguished awards for major contributions to science

Laura Carter | School of Science

Four MIT scientists are among the 20 recipients of the 2021 Academy Honors for major contributions to science, the National Academy of Sciences (NAS) announced at its annual meeting. The individuals are recognized for their "extraordinary scientific achievements in a wide range of fields spanning the physical, biological, social, and medical sciences."

The awards recognize: Pablo Jarillo-Herrero, for contributions to the fields of nanoscience and nanotechnology through his discovery of correlated insulator behavior and unconventional superconductivity in magic-angle graphene superlattices; Aviv Regev, for using interdisciplinary information or techniques to solve a contemporary challenge; Susan Solomon, for contributions to understanding and communicating the causes of ozone depletion and climate change; and Feng Zhang, for pioneering achievements developing CRISPR tools with the potential to diagnose and treat disease.

Professor Pablo Jarillo-Herrero

In addition to these awards, the National Academy of Sciences elected 120 new members to the academy, including five from MIT — Dan Freedman, Robert Griffin, Larry Guth, Stephen Morris, and Gigliola Staffilani — in recognition of their "distinguished and continuing achievements in original research."

Pablo Jarillo-Herrero: Award for Scientific Discovery

Pablo Jarillo-Herrero, a Cecil and Ida Green Professor of Physics, is the recipient of the NAS Award for Scientific Discovery for his pioneering developments in nanoscience and nanotechnology, which is presented to scientists in the fields of astronomy, materials science, or physics. His findings expand nanoscience by demonstrating for the first time that orientation can be used to dramatically control nanomaterial properties and to design new nanomaterials. This work lays the groundwork for developing a whole new family of 2-D materials and has had a transformative impact on the field and on condensed-matter physics.

The biannual award recognizes "an accomplishment or discovery in basic research, achieved within the previous five years, that is expected to have a significant impact on one or more of the following fields: astronomy, biochemistry, biophysics, chemistry, materials science, or physics."

In 2018, his research group discovered that by rotating two layers of graphene relative to each other by a magic angle, the bilayer material can be turned from a metal into an electrical insulator or even a superconductor. This discovery has fostered new theoretical and experimental research, inspiring the interest of technologists in nanoelectronics. The result is a new field in condensed-matter physics that has the potential to result in materials that conduct electricity without resistance at room temperature.


Professor Aviv Regev

Aviv Regev: James Prize in Science and Technology Integration

Aviv Regev, who is a professor of biology, a core member of the Broad Institute of Harvard and MIT, a member of the Koch Institute, and a Howard Hughes Medical Institute investigator, has been selected for the inaugural James Prize in Science and Technology Integration, along with Harvard Medical School professor Allon Klein, for "their concurrent development of now widely adopted massively parallel single-cell genomics to interrogate the gene expression profiles that define, at the level of individual cells, the distinct cell types in metazoan tissues, their developmental trajectories, and disease states, which integrated tools from molecular biology, engineering, statistics, and computer science."

The prize recognizes individuals "who are able to adopt or adapt information or techniques from outside their fields" to "solve a major contemporary challenge not addressable from a single disciplinary perspective."

Regev is credited with forging new ways to unite the disciplines of biology, computational science, and engineering as a pioneer in the field of single-cell biology, including developing some of its core experimental and analysis tools, and their application to discover cell types, states, programs, environmental responses, development, tissue locations, and regulatory circuits, and deploying these to assemble cellular atlases of the human body that illuminate mechanisms of disease with remarkable fidelity.

Susan Solomon: Award for Chemistry in Service to Society

Susan Solomon, the Lee and Geraldine Martin Professor of Environmental Studies in the Department of Earth, Atmospheric and Planetary Sciences who holds a secondary appointment in the Department of Chemistry, is the recipient of the Award for Chemistry in Service to Society for "influential and incisive application of atmospheric chemistry to understand our most critical environmental issues — ozone layer depletion and climate change — and for her effective communication of environmental science to leaders to facilitate policy changes."

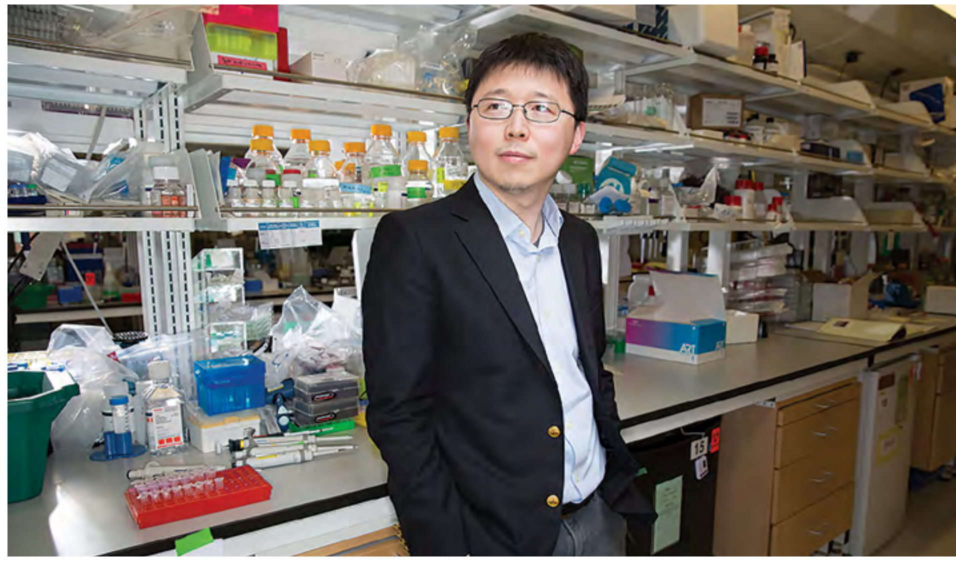
The award is given biannually for "contributions to chemistry, either in fundamental science or its application, that clearly satisfy a societal need."

Solomon is globally recognized as a leader in atmospheric science, notably for her insights in explaining the cause of the Antarctic ozone hole. She and her colleagues have made important contributions to understanding chemistry-climate coupling, including pioneering research on the irreversibility of global warming linked to anthropogenic carbon dioxide emissions, and on the influence of the ozone hole on the climate of the southern hemisphere.

Her work has had an enormous effect on policy and society, including the transition away from ozone-depleting substances and to environmentally benign chemicals. The work set the stage for the Paris Agreement on climate change, and she continues to educate policymakers, the public, and the next generation of scientists.


Professor Susan Solomon

> “[Professor Gigliola Staffilani] is one of 59 new members who are women, the most elected to the NAS in a single year.”



Professor Feng Zhang

Feng Zhang: Richard Lounsbery Award

Feng Zhang, who is the James and Patricia Poitras Professor of Neuroscience at MIT, an investigator at the McGovern Institute for Brain Research and the Howard Hughes Medical Institute, a professor of brain and cognitive sciences and biological engineering at MIT, and a core member of the Broad Institute of MIT and Harvard, is the recipient of the Richard Lounsbery Award for pioneering CRISPR-mediated genome editing.

The award recognizes “extraordinary scientific achievement in biology and medicine” as well as stimulating research and encouraging reciprocal scientific exchanges between the United States and France.

Zhang continues to lead the field through the discovery of novel CRISPR systems and their development as molecular tools with the potential to diagnose and treat disease, such as disorders affecting the nervous system. His contributions in genome engineering, as well as his earlier work developing optogenetics, are enabling a deeper understanding of behavioral neural circuits and advances in gene therapy for treating disease.

In addition, Zhang has championed the open sharing of the technologies he has developed through extensive resource sharing. The tools from his lab are being used by thousands of scientists around the world to accelerate research in nearly every field of the life sciences. Even as biomedical researchers around the world adopt Zhang’s discoveries and his tools enter the clinic to treat genetic diseases, he continues to innovate and develop new technologies to advance science.

New NAS members

Gigliola Staffilani, the Abby Rockefeller Mauzé Professor of Mathematics, is a mathematical analyst whose research focuses on dispersive nonlinear partial differential equations. She is one of 59 new members who are women, the most elected to the NAS in a single year.

Dan Freedman is a professor emeritus in MIT’s departments of Mathematics and Physics. His research is in quantum field theory, quantum gravity, and string theory, with an emphasis on the role of supersymmetry.

Claude E. Shannon Professor of Mathematics Larry Guth’s research interests are in metric geometry, with a focus on systolic inequality, and on finding connections between geometric inequalities and topology.

Robert Griffin, the Arthur Amos Noyes Professor of Chemistry, is also director of the Francis Bitter Magnet Laboratory. He devotes a large fraction of the Griffin Group’s research efforts to develop new magnetic resonance techniques to study molecular structure and dynamics.

The NAS is charged with providing independent, objective advice to the nation on matters related to science and technology as well as encouraging education and research, recognize outstanding contributions to knowledge, and increasing public understanding in matters of science, engineering, and medicine. Winners received their awards, which include a monetary prize, during a virtual ceremony at the 158th NAS Annual Meeting.

Friends of MIT Biology celebrate an unusual year

Saima Sidik | Department of Biology

The 2021 Friends of Biology virtual gathering featured keynote addresses and talks (from top to bottom, left to right): Nergis Mavalvala, Alan Grossman, Daniel E. Griffin, Grace Johnson, Bridget Begg, and Charlie Shi. Photos courtesy of the Department of Biology.

On Feb. 25, members of the Department of Biology came together with alumni, industry representatives, and supporters to review the department's challenges and accomplishments during the third annual Friends of Biology gathering. This year's event was held virtually due to Covid-19 restrictions. Although everyone yearns for in-person events to resume, the new format came with some benefits: This year's event was the largest Friends of Biology gathering yet, with 195 attendees from 12 countries. Also, because participants didn't need to travel, it was possible to hold the event in February without concern for weather disrupting plans.

Keynote speakers Nergis Mavalvala, dean of the School of Science, and Alan Grossman, head of the Department of Biology, addressed the virtual gathering.

"We are all, I'm sure, acutely aware that we're meeting together in digital space rather than physical space," Mavalvala said. She added that the pandemic highlights the importance of the basic research conducted by the members of the Department of Biology. "Most of the technologies of tomorrow are predicated on the discoveries of today," she said.

Grossman noted that the Department of Biology's new class, 7.00 (Covid-19, SARS-CoV-2, and the Pandemic) has aided the MIT community and the public in navigating this unusual year by providing a reliable source for Covid-related information. The course, conceived by Grossman in spring 2020 and coordinated by Richard Young from the Department of Biology and Facundo Batista from the Ragon Institute of MGH, MIT, and Harvard, included 14 lectures on topics ranging from the molecular biology of the virus to epidemiology and vaccinology. Collectively, the lectures garnered more than 500,000 views. As our understanding of the virus and its implications for daily life continue to evolve, the department intends to offer an updated version this coming fall.

A central theme of the evening was supporting and educating the next generation of scientists — always a high priority for the department. "I take great pride in the teaching and mentoring that we do," Grossman said. "It's really one of our top priorities."

The past year was challenging for many students, who had to vacate their labs in March and, in many cases, are still working in labs that are operating with reduced capacity. During the second half of the program, three graduate students presented their recent discoveries to demonstrate how the department has continued its work despite these disruptions.

Grace Johnson from Professor Gene-Wei Li's lab introduced the central dogma of biology, in which DNA is used to encode mRNA, which is, in turn, translated into proteins. In the most commonly studied bacterium, *Escherichia coli*, the molecular machines that make mRNA and proteins work at nearly the same speed, linking the two processes. Johnson showed that in the less-studied bacterium *Bacillus subtilis*, the machinery that produces mRNA speeds along DNA, while the machinery that makes proteins lags behind. Her work highlights the importance of studying a diversity of organisms rather than drawing conclusions based only on the most common models.

Bridget Begg from Professor Christopher Burge's lab described her work on the process by which cells splice mRNA to create multiple versions, which can then be translated into different proteins. When this process of "alternative splicing" fails, it can lead to conditions like autism, epilepsy, and heart disease. Begg identified new mRNA sequences with which the proteins that control alternative splicing can interact, which could prove critical to understanding these diseases.

Lastly, Charlie Shi from Professor David Bartel's lab described his work on a mechanism involving microRNAs that cells use to regulate gene expression. MicroRNAs are small pieces of RNA that bind to mRNA and, in most cases, trigger cells to degrade the mRNA. Shi's work uncovered an alternative mechanism in which mRNA binding causes the microRNAs to be destroyed instead, turning the canonical situation on its head. Shi believes that this mechanism for microRNA destruction may play an important role in embryonic development.

"Most of the technologies of tomorrow are predicated on the discoveries of today."

Following the presentation portion of the program, participants had a chance to mingle during a virtual networking session.

The event was organized by Daniel E. Griffin, the Department of Biology's senior development officer, and Lizzie Army from the MIT Alumni Association.

"It was wonderful to see so many attendees from outside the biology department join the third annual Friends of Biology gathering," Griffin says. "It's clear that Covid-19 has highlighted the importance of basic biological research for people across all disciplines. We're glad to see so many people who are eager to connect with the department to learn more."

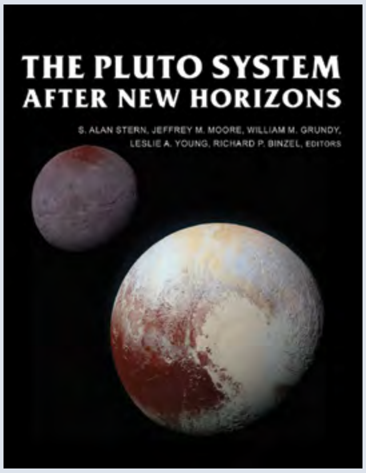
As Grossman noted in his keynote address: "Looking ahead, there are many unknowns." But the successes highlighted at the gathering demonstrate the resilience of the department in the face of this uncertainty.

Books from Science

A giant leap for dwarf planets

Richard Binzel and colleagues share new data about Pluto from the New Horizons mission in a foundational volume

Laura Carter | School of Science



In 2015, the New Horizons mission gave us the first glimpse at Pluto, one of our most distant neighbors in the solar system. Thanks to the flyby, scientists have been able to learn a lot more about the mysterious dwarf planet and its satellites.

In a new volume titled *The Pluto System After New Horizons*, published in July 2021 by the University of Arizona Press, Richard Binzel, a professor in the Department of Earth, Atmospheric and Planetary Sciences, and other colleagues compile a basis for our understanding of Pluto using data returned from New Horizons. Co-edited by Binzel, who is a co-investigator with S. Alan Stern, NASA's New Horizon's principal investigator and the volume's lead editor, the book is intended to be "an enduring foundation for ongoing study and understanding of the Pluto system."

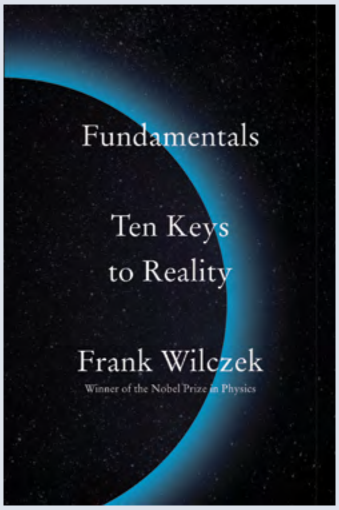
While sharing what is known, the book is intended to be a foundation for future work. By providing "insights into the nature of dwarf planets and Kuiper Belt objects," *The Pluto System After New Horizons* could guide future research and maybe even the next mission to the far end of the solar system.

Find out more about the book at the University of Arizona Press.

Nobel laureate's "ten keys to reality"

To understand ourselves and our place in the universe, "we should have humility but also self-respect," writes physicist Frank Wilczek

Laura Carter | School of Science



In his new book, *Fundamentals: Ten Keys to Reality*, published by Penguin Press, Frank Wilczek writes that the lessons were a revelation: "To experience the deep harmony between two different universes — the universe of beautiful ideas and the universe of physical behavior — was for me a kind of spiritual awakening. It became my vocation. I haven't been disappointed."

Wilczek, who is the Herman Feshbach Professor of Physics at MIT, has since made groundbreaking contributions to our fundamental understanding of the physical world, for which he has been widely recognized, most notably in 2004 with the Nobel Prize in Physics, which he shared with physicists David Gross and David Politzer. He has also authored several popular science books on physics and the history of science.

In his new book, he distills scientists' collective understanding of the physical world into 10 broad philosophical themes, using the fundamental theories of physics, from cosmology to quantum mechanics, to reframe ideas of space, time, and our place in the universe.

"People wrestle with what the world is all about," Wilczek tells MIT News. "They're not concerned with knowing precisely what Coulomb's law is, but want to know more about questions like the ancient Greeks asked: What is space? What is time? So in the end, I came up with 10 assertions, at the levels of philosophy but backed up by very concrete facts, to organize what we know."

Read more of this article at MIT News.

Michale Fee appointed head of the Department of Brain and Cognitive Sciences

Tristan Davies | Brain and Cognitive Sciences


Professor Michale Fee. Photo: Justin Knight

Michale Fee, the Glen V. and Phyllis F. Dorflinger Professor of Brain and Cognitive Sciences, has been named as the new head of the Department of Brain and Cognitive Sciences (BCS) effective May 1, 2021.

Fee, who also is an Investigator in the McGovern Institute for Brain Research, succeeds James DiCarlo, the Peter de Florez Professor of Neuroscience, who announced in December that he was stepping down to become director of the MIT Quest for Intelligence.

“I want to thank Jim for his impressive work over the last nine years as head,” says Fee. “I know firsthand from my time as associate department head that BCS is in good shape and on a steady course. Jim has set a standard of transparent and collaborative leadership, which is a solid foundation for making our community stronger on all fronts.” Fee notes that his first mission is to continue the initiatives begun under DiCarlo’s leadership — in academics (especially Course 6-9); mentoring; and diversity, equity, inclusion, and justice — while maintaining the highest standards of excellence in research and education.

“Jim has overseen significant growth in the faculty and its impact, as well as important academic initiatives to strengthen the department’s graduate and undergraduate programs,” says Nergis Mavalvala, dean of the School of Science. “His emphasis on building ties among BCS, the McGovern Institute for Brain Research, and the Picower Institute for Learning and Memory has brought innumerable new collaborations among researchers and helped solidify Building 46 and MIT as world leaders in brain science.”

Fee earned his BE in engineering physics in 1985 at the University of Michigan, and his PhD in applied physics at Stanford University in 1992, under the mentorship of Nobel Laureate Stephen Chu. His doctoral work was followed by research in the Biological Computation Department at Bell Laboratories. He joined MIT and BCS as an associate professor in 2003 and was promoted to full professor in 2008.

He has served since 2012 as associate department head for education in BCS, overseeing significant evolution in the department’s academic programs, including a complete reworking of the Course 9 curriculum and the establishment in 2019 of Course 6-9 (computation and cognition), in partnership with EECS.

In his research, Fee explores the neural mechanisms by which the brain learns complex sequential behaviors, using the learning of song by juvenile zebra finches as a model. He has brought new experimental and computational methods to bear on these questions, identifying a number of circuits used to learn, modify, time, and coordinate the development and utterance of song syllables.

“His work is emblematic of the department in that it crosses technical and disciplinary boundaries in search of the most significant discoveries,” says DiCarlo. “His research background gives Michale a deep appreciation of the importance of every sub discipline in our community and a broad understanding of the importance of their connections with each other.”

Fee has received numerous honors and awards for his research and teaching, including the MIT Fundamental Science Investigator Award in 2017, the MIT School of Science Teaching Prize for Undergraduate Education in 2016, the BCS Award for Excellence in Undergraduate Teaching in 2015, and the Lawrence Katz Prize for Innovative Research in Neuroscience from Duke University in 2012.

Fee will be the sixth head of the department, after founding chair Hans-Lukas Teuber (1964–77), Richard Held (1977–86), Emilio Bizzi (1986–97), Mriganka Sur (1997–2012), and James DiCarlo (2012–21).

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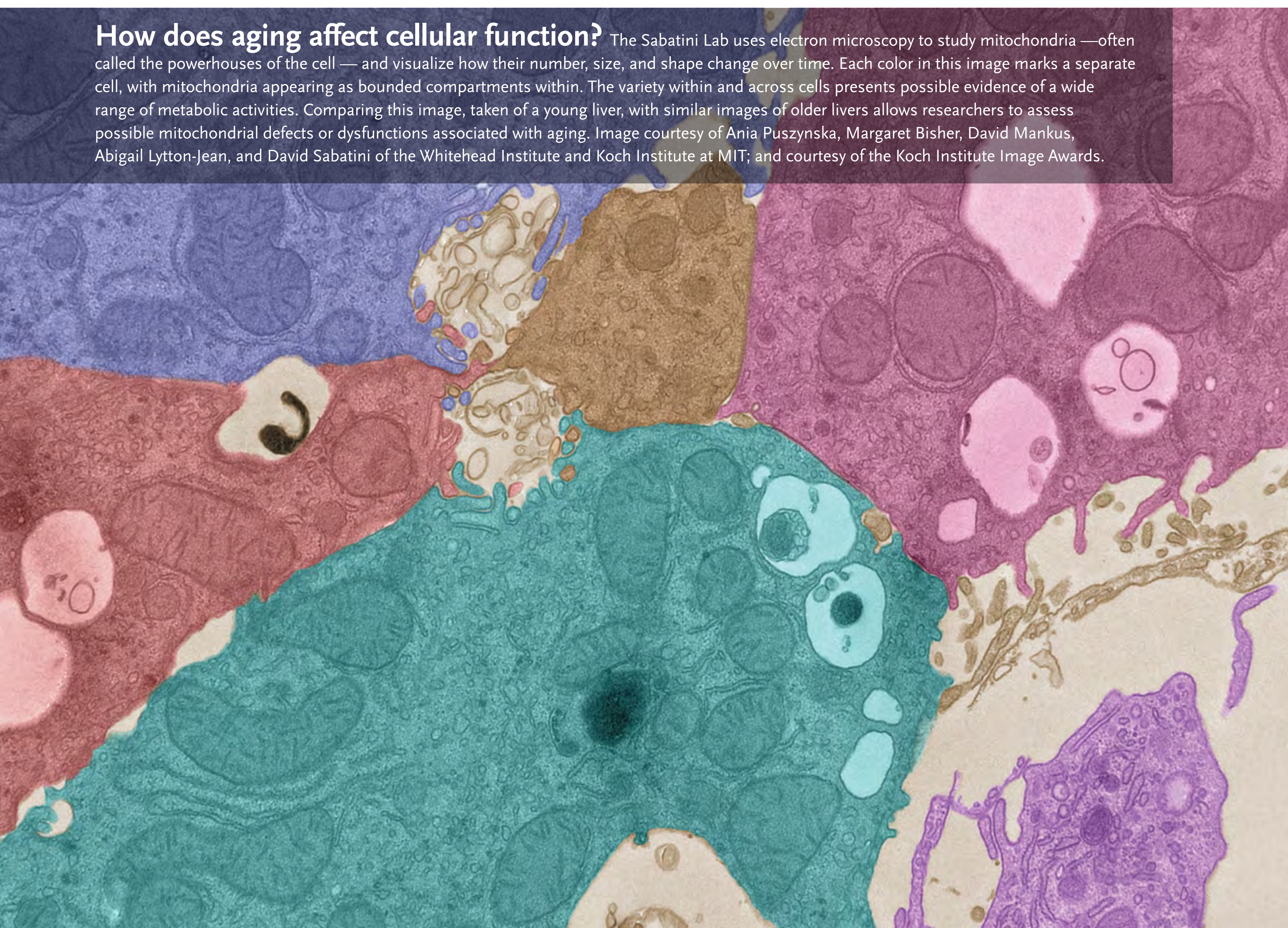

How does aging affect cellular function? The Sabatini Lab uses electron microscopy to study mitochondria —often called the powerhouses of the cell — and visualize how their number, size, and shape change over time. Each color in this image marks a separate cell, with mitochondria appearing as bounded compartments within. The variety within and across cells presents possible evidence of a wide range of metabolic activities. Comparing this image, taken of a young liver, with similar images of older livers allows researchers to assess possible mitochondrial defects or dysfunctions associated with aging. Image courtesy of Ania Puszynska, Margaret Bisher, David Mankus, Abigail Lytton-Jean, and David Sabatini of the Whitehead Institute and Koch Institute at MIT; and courtesy of the Koch Institute Image Awards.