Institute for Medical Engineering and Science

The vision of MIT's Institute for Medical Engineering and Science (IMES) is to pioneer novel research paradigms and curricula that bring together engineering, science, and medicine to advance human science and health and to educate students whose work will seamlessly span these historically separate realms.

Founded in 2012 and comprising almost 1,000 faculty members, students, researchers, and staff, IMES focuses on three key areas: studying the fundamental processes that drive disease and wellness, developing new medical devices and products that address clinical challenges, and educating the next generation of biomedical engineers and clinician-scientists through the pioneering Harvard-MIT Program in Health Sciences and Technology (HST). IMES is an integrative force across MIT and the health care community at large, bringing together academia, industry, and medical institutions to work toward these common goals.

HST is one of the world's oldest interdisciplinary educational programs focused on translational medical science and engineering. Founded in 1970, this inter-institutional collaboration among MIT, Harvard, and local teaching hospitals provides students with a deep understanding of the biological sciences and engineering combined with extensive hands-on clinical experience. HST maintains an office at the Harvard Medical School (HMS) Longwood campus in Boston as one of the five medical societies at HMS and reports to the HMS dean for medical education and dean for research operations and global programs.

Centers, Initiatives, and Accomplishments

IMES houses several centers that extend resources to investigators and students. For example, the Clinical Research Center (CRC), supported by the School of Engineering and the Office of the Vice President for Research, supports human subject research, medical device and diagnostic innovation, and data sciences. The center has renovated and expanded facilities offering five newly configured specialized labs, a collaboration hub, and investigator space housed in Building E25. It is envisioned that CRC will expand to a clinical and translational research center pending approval by the Dean's Council in September. In this new embodiment, CRC will work closely with the Committee on the Use of Humans as Experimental Subjects, MIT Medical, and the new Data Security Center at MIT. Outside of MIT, the center will work with schools (Tufts University, Harvard University, Harvard Medical School), hospitals, and agencies (Food and Drug Administration). In addition, the Center for Microbiome Informatics and Therapeutics, directed by Eric Alm and Ramnik Xavier, brings together researchers and clinicians to improve human health by diagnosing, treating, and preventing diseases associated with the human microbiome.

IMES is also home to several initiatives and strategic partnerships that provide research and educational opportunities within and outside of MIT.

- The MIT-Sekisui House Program, a collaboration among MIT, eSolutions, and Sekisui House, is designed to advance in-home wellness monitoring and early detection systems (EDSs). The program will innovate to accelerate EDS translation and stimulate market opportunities.
- IMES and the Tufts Clinical and Translational Science Institute are collaborating to uncover clinical insights that can help fine-tune early device testing. They are also working to design sequences of promising ideas so that they are more likely to become successful medical applications.
- One Brave Idea, a collaboration among Brigham and Women's Hospital, IMES faculty members, and other researchers, will pursue new biomarkers for atherosclerosis (hardening of the arteries), a condition that kills about 500,000 people in the United States every year.
- IMES is creating opportunities for close work with the Ragon Institute, whose mission is to contribute to the accelerated discovery of an HIV/AIDS vaccine. Several IMES faculty members are associated with Ragon and working to increase research collaborations. IMES PhD students serve as teaching assistants for Ragon director Bruce Walker's HST.S46 Evolution of an Epidemic course in South Africa, sponsored in part by IMES.
- Massachusetts General Hospital (MGH) is a key IMES partner in many spheres. Through this partnership, IMES and MGH pursue projects unlikely to receive funding from standard federal grants, including work in noninvasive diagnosis and neurological, infectious, and autoimmune diseases.
- Philips HealthCare, which has an important research facility in Boston, is providing significant funding while working with members of the IMES faculty on areas of mutual interest, primarily medical analytics and new devices.
- MIT linQ is a collaborative initiative focused on increasing the potential of innovative research to benefit society and the economy. The linQ portfolio of international innovation programs includes Catalyst, IMPACT, and IDEA2 Global.
- IMES has an active collaboration with the Institut Químic de Sarrià (IQS) in Barcelona called the MIT-Spain Program. This collaboration includes bidirectional exchanges of faculty and students as well as the joint design of an IMES-IQS certificate program and the development of sponsored research agreements with industry partners.

Diversity, Equity, and Inclusion

Building on the initial momentum that began at the end of the prior reporting period, IMES faculty, students, and staff have continued an active dialogue around diversity, equity, and inclusion (DEI). Throughout the summer and fall, IMES and HST held monthly town halls to enable DEI discussions. These conversations helped catalyze the formation of an IMES DEI steering committee composed of students, staff, and faculty to help develop and enact recommendations to promote DEI and belonging. In the same time frame, a group of support staff came together to found the Diversity and Inclusion at IMES/HST Learning Club to engage in educational activities together and move toward creating an anti-racist, anti-discriminatory work environment.

Specific activities within IMES and HST this year included:

- Recruiting of prospective graduate students at virtual conferences such as the Society for Advancement of Chicanos/Hispanics and Native Americans in Science conference and the Annual Biomedical Research Conference for Minority Students.
- An application assistance program offered by HST student volunteers designed to address disparities in support that different applicants may have during the application process. In fall 2020, 23 current HST students were paired with 28 prospective applicants to provide peer feedback on application materials.
- The addition of a personal statement to the graduate application. This pilot was well received, with the majority of faculty on the admissions committee finding the additional information valuable in understanding and contextualizing candidates' experiences. Also, admitted applicants indicated that the additional essay prompt signaled HST's commitment to DEI and allowed them to include information about their backgrounds that they might not otherwise have felt welcome to share.
- HST's addition to the Sloan-MIT University Center for Excellence in Mentoring alongside the original four School of Engineering departments participating in this innovative program designed to center the recruitment, retention, and academic success of underrepresented minority doctoral students.
- Unconscious bias seminars for faculty and students delivered by Bryant Marks of Morehouse College and the National Training Institute on Race and Equity.
- Curricular changes in HST.590 Biomedical Engineering Seminar Series, required for all first- and second-year PhD students, and HST.201 Introduction to Clinical Medicine at Mt. Auburn Hospital to emphasize racial disparities in health care and biomedical research.

Resource Development

As was the case across campus, IMES development efforts had to adapt to pandemic era restrictions. Our two primary lecture series have not taken place since 2019, but we are looking forward to restarting them soon. On the plus side, the capital project funded with a gift from Sekisui House in FY2019 was able to start and finish with no impact on others in Building E25. This renovated Clinical Research Center has been seeing patients since its soft opening earlier this year.

Meetings with donors and prospects continued to be held via Zoom, allowing us to advance prospective gift conversations. A gift of $375,000 to be paid over five years was secured to support a postdoctoral student working on Professor Roger Mark's Medical Information Mart for Intensive Care (MIMIC) project. This particular fellowship will support researchers coming from Brazil who are affiliated with São Paulo–based Hospital Israelita Albert Einstein. The hospital hopes to build a MIMIC database composed of local data that properly reflects the diversity of their population. The fellowship was funded by a new international donor to MIT, Frederico Trajano, who was introduced to our work by Marco Munoz.

James Collins and affiliate faculty member Regina Barzilay were selected as recipients of funds from The Audacious Project, a collaborative funding initiative of TED (technology, entertainment, and design) and The Bridgespan Group. The multimillion-dollar grant will support the response to the antibiotic resistance crisis through the development of new classes of antibiotics to protect patients against some of the world's deadliest bacterial pathogens.

The Sita Foundation provided its fifth expendable fellowship for IMES. Funded by the Ullal family, Elazer Edelman has met several times with the primary family contact, Adeeti Ullal, who is a 2013 graduate of the HST Medical Engineering and Medical Physics Program (MEMP) and a member of the School of Engineering Dean's Advisory Council. Conversations have continued about the possibility of the Ullal family endowing this fellowship, but at this time the family would prefer to continue giving annual expendable gifts.

Another MEMP alumna, Catherine Corrigan, spoke to our HST.590 class in early 2021. Students enjoyed hearing about how she leveraged her work at MIT into a successful business career. She has been a regular donor since her graduation from HST in 1996, recently doubling that gift after meeting Professor Edelman.

Maura Ridge, the IMES leadership giving officer, worked with Heather Kispert Hagerty, assistant dean for development in the School of Engineering, and other School of Engineering giving officers to create a comprehensive strategic development plan designed to raise awareness, strengthen relationships, and garner financial support for IMES initiatives and academic programs. They have also been working with Resource Development on building up school development officers' prospect portfolios.

Academic Program

HST is among the largest biomedical engineering and physician-scientist training programs in the United States, with 307 students enrolled in its graduate degree programs during academic year 2021.

- Medical Engineering and Medical Physics Program PhD students: 120, including two MEMP/MD students
- MD and MD/PhD students: 189, including the two MEMP/MD students mentioned above

HST graduate students work with faculty members from MIT, Harvard, and affiliated teaching hospitals. Whether pursuing careers in medicine, research, industry, or government, HST graduates have made outstanding contributions to advances in human health.

HST's MEMP PhD program, housed in IMES, trains students as engineers or physical scientists who also possess extensive knowledge of medical sciences. The program provides preclinical and clinical training to students. On average, students complete the PhD program in less than six years, and in some cases they also pursue an MD. MEMP PhD students are extremely successful in obtaining outside funding support for their graduate studies, with 39% of these students holding external fellowships in AY2021.

Two specialized programs within MEMP are the Neuroimaging Training Program and the PhD Program in Bioastronautics. The Neuroimaging Training Program is supported by a grant from the National Institute of Biomedical Imaging and Bioengineering. Laurence Lamson Robbins Professor Bruce Rosen and Professor Randy Gollub, both members of the HST faculty based at the Martinos Center at Massachusetts General Hospital, co-direct the program. Trainees are identified from among those already enrolled in MEMP with specific interests in neuroimaging. They take additional classes in a curriculum tailored for the program and participate in networking and enrichment activities with faculty and students who have related research interests.

The PhD Program in Bioastronautics was founded by Professor Emeritus Laurence Young (who to our great regret passed away the first week of August) and is currently directed by affiliate faculty member Dava Newman. This program combines the biomedical training of HST's MEMP PhD curriculum with hands-on research exposure at the National Aeronautics and Space Administration (NASA) Johnson Space Center. One or two new students enroll in MEMP/Bioastro each year, joining a small, focused cohort of approximately seven students. The program was established in 2006 with the support of an education grant from the National Space Biomedical Research Institute. This financial support ended in 2017, and alternative funding has not yet been secured. IMES/HST will continue to offer the academic program as part of MEMP without dedicated funding.

The HST MD program, housed at Harvard Medical School, is aimed at students interested in a research-based medical career. While eligible to complete the program in four years, many students take an optional fifth year to engage in more extensive research. Approximately 80% of HST MD alumni follow career paths in academia.

Graduate Education in Medical Sciences Certificate Program

The Graduate Education in Medical Sciences (GEMS) certificate program is open to doctoral students in MIT's Schools of Engineering and Science who are interested in working at the intersection where engineering and science meet medicine and real-world health care. GEMS runs concurrently with the normal course of an MIT PhD program and can be completed in two years without prolonging a typical PhD career. In addition to coursework in pathology and pathophysiology, participants attend seminars with HST students and engage in individually tailored clinical experiences. GEMS students learn how advances in basic science and engineering become medically relevant therapies and tools for the improvement of human health while developing a professional network that includes medical researchers, clinicians, and physician-scientists.

GEMS was initially established with support from a Howard Hughes Medical Institute (HHMI) program that encouraged graduate schools to integrate medical knowledge and an understanding of clinical practice into PhD curricula. Thirty-two MIT PhD students enrolled in GEMS between 2007 and 2011. The program, which became dormant after the HHMI funding ended, was revitalized after the founding of IMES. Since 2012, 33 new students have enrolled in GEMS.

Due to the COVID-19 pandemic, GEMS did not offer admissions during AY2021.

Summer Institute

Patterned after MIT's Summer Research Program, HST offers a specialized Summer Institute program in biomedical optics in collaboration with the Wellman Center for Photomedicine at Massachusetts General Hospital. Due to the COVID-19 pandemic, the 2021 Summer Institute was held virtually, with 32 students enrolled.

This program offers a unique opportunity for outstanding undergraduate college students considering a career in biomedical engineering and/or medical science. Through hands-on research and in-depth lectures, participants learn about biomedical optics and engage in the application of this field to solving problems in human health. In addition, through individual tutorials and workshops, students learn to communicate their research findings effectively in written and oral formats. Shared living arrangements and a variety of technical and social activities enable Summer Institute participants to develop a network of peers and forge connections with faculty working in the field.

Honors and Awards

Faculty Honors and Promotions

We are honored to have three of our esteemed faculty members assume chairs in IMES effective July 1, 2021. Elfar Adalsteinsson will hold the Eaton-Peabody Professorship, Leonid Mirny will hold the Distinguished Professorship in Medical Engineering and Science, and Collin Stultz will hold the Nina T. and Robert H. Rubin Professorship.

Also, effective July 1, 2021, Arup Chakraborty has been named Institute Professor, the highest honor bestowed upon MIT faculty members. Professor Chakraborty is the founding director of IMES and is a pioneer in applying computational techniques to challenges in the field of immunology, including vaccine development.

Regina Barzilay received the Association for the Advancement of Artificial Intelligence Squirrel AI Award for Artificial Intelligence for the Benefit of Humanity; the United Nations Educational, Scientific and Cultural Organization (UNESCO) Netexplo Award; and the American Association for Clinical Chemistry Wallace H. Coulter Lectureship Award.

Sangeeta Bhatia received an honorary degree from the Icahn School of Medicine at Mount Sinai; was portrayed in a National Academy of Sciences biography, *Women in STEM*; and was featured in *Genius Within*, an art installation in Kendall Square designed by MIT and the Cambridge-based youth empowerment organization Innovators for Purpose.

Emery Brown, the Edward Hood Taplin Professor of Medical Engineering, became an elected member of the Simons Foundation Board of Trustees and the Board of Trustees of the Gladstone Institute (University of California at San Francisco). In addition, he received the 2020 John and Elizabeth Phillips Award from the Phillips Exeter Academy and the 2020 Swartz Prize for Computational and Theoretical Neuroscience from the Society for Neuroscience.

Arup Chakraborty received the Outstanding Graduate Teaching Award from the Department of Chemical Engineering.

Kwanghun Chung was promoted to associate professor with tenure.

James Collins received the Dickson Prize in Medicine.

Elazer Edelman received the Dr. Joseph Loscalzo Award for the best paper in the journal *Circulation* and the Society for Magnetic Resonance Angiography Best Clinical Science Award. In addition, he presented the Ramzi S. Cotran Memorial Lecture at Harvard Medical School and was the keynote speaker at the American Heart Association's Science Catalyst and the Annual Meeting Research Day at the Paulista School of Medicine of the Federal University of São Paulo.

Polina Golland was named a fellow of the American Institute for Medical and Biological Engineering in 2021 and received the Ruth and Joel Spira Awards for Excellence in Teaching.

Robert Langer was recognized with the Medalha da Ciência (the Portuguese government's highest distinction for scientists), the Maurice-Marie Janot Award, and the Surfaces in Biomaterials Foundation's Excellence in Biomaterials Science Award. He was also named a fellow of the American Association for Cancer in 2020.

Dava Newman was named the director of the Media Lab. She was also listed as one of The World's Most Influential Women Engineers by *Forbes.* In addition, she became a governing member of the International Space University, won the American Institute of Aeronautics and Astronautics Space Architecture Best Paper Award and NASA Ames Honor Awards, and was named an Institute of Space Commerce Senior Fellow.

Ellen Roche was promoted to associate professor without tenure in 2021. She received a National Science Foundation CAREER Award, a National Institutes of Health (NIH) Trailblazer Award, a Charles H. Hood Foundation Award for Excellence in Child Health Research, the Junior Bose Teaching Award, and the Thomas A. McMahon Award for Mentoring. In addition, she was appointed to the W.M. Keck Foundation Career Development Professorship.

Alex Shalek was promoted to associate professor with tenure and received the National Institute on Drug Abuse Avant Garde Pioneer (DP1) Award.

Collin Stultz was a Phi Beta Kappa visiting scholar.

Faculty Mentoring and Teaching Awards

Yonatan Grad was presented the HST Seidman Prize for MD Research Mentorship.

Clyde Crumpacker and Harvey Simon were honored with HST's Irving M. London Teaching Award.

Junne Kamihara won HST's Thomas A. McMahon Mentoring Award.

Patty Cunningham was honored with HST's Roger G. Mark Outstanding Service Award (Faculty or Staff).

Edward Benz, Nancy Berliner, Sudha Biddinger, David Breault, Jeff Behrens, and Nathaniel Price were recognized with HST Director's Awards for their outstanding teaching contributions in HST.

Student Honors and Awards

American Society of Hematology 2021 Hematology Opportunities for the Next Generation of Research Scientists (HONORS) Award: Kameron Kooshesh (HST MD)

Forbes 30 under 30 in Healthcare: Eriene-Heidi Sidhom (PhD/HST MD, 2021)

Multiculturalism and Diversity Award (HMS): Senan Ebrahim (PhD/HST MD, 2021)

Martin Prince Scholarship for Student Innovation (HMS): Bailey Ingalls (HST MD)

Leon Resnick Memorial Prize (HMS): Erik Bao (HST MD, 2021)

Dr. Sirgay Sanger Award (HMS): Anthony Jang (HST MD, 2021)

Seidman Prize for Outstanding HST Senior Medical Student Thesis (HMS): Erik Bao (HST MD, 2021)

HST Outstanding Teaching Award (Student): Timothy Caradonna (PhD/HST MD)

HST Roger G. Mark Outstanding Service Award (Student): Rory Mather (PhD/HST MD)

La Caixa Fellowship: Maria Carmen Martin Alonso (MEMP PhD)

Angela Leong Fellowship (MIT): Mingyu Yang (MEMP PhD)

McGovern Institute Rising Stars in Neuroscience (MIT): Nicholas Meirhaeghe (MEMP PhD) and Enrique Toloza (PhD/HST MD)

School of Engineering Graduate Student Extraordinary Teaching and Mentoring Award (MIT): Brian Chang (MEMP PhD/HST MD)

Whitaker Health Sciences Fund Fellowship (MIT): Jordan Harrod (MEMP PhD)

National Science Foundation Graduate Research Fellowships: Elizabeth Healey (MEMP PhD) and Amanda Hornick (MEMP PhD)

Sadie Collective List of Black Women Data Scientists to Know: Jordan Harrod (MEMP PhD)

Paul and Daisy Soros Fellowships for New Americans: Alaleh Azhir (HST MD), Brian Chang (MEMP PhD/HST MD), James Diao (HST MD), ChangWon Lee (HST MD), Archana Podury (HST MD), and Enrique Toloza (PhD/HST MD)

Research Program

With the ongoing COVID-19 pandemic in 2020 and 2021, many IMES faculty members continued COVID-19 research. Also, IMES led the effort at MIT (and in New England) to provide personal protective equipment (PPE) to academic medical centers, inner-city assisted living facilities, and many other institutions. At the peak of Covid, our efforts supplied one in every five PPE items across New England. IMES faculty and affiliates harnessed inspired design and manufacturing to create a new face shield that can be made for pennies, shipped in hundreds as flat, and assembled on site in seconds. These shields have now been made available around the world. Finally, IMES is the North American representative in an international effort to ensure equal access to PPE around the world and in all populations.

Core Faculty

In ongoing collaborations with MIT colleagues (Polina Golland, Jacob White, and Luca Daniel), Boston Children's Hospital, and Massachusetts General Hospital, Elfar Adalsteinsson and his team pursue imaging problems with applications in human health. Among recent methodological contributions to fetal magnetic resonance imaging (MRI) are novel designs of spatially selective radio frequency (RF) excitations of the fetal brain by both a restricted two-dimensional slice and a three-dimensional (3D) inner-volume selection. This approach exploits conventional hardware, including a single-channel RF pulse and three gradient fields, as well as spatially nonlinear fields under the control of a so-called shim array proposed by our MGH colleagues. Taken together, these magnetic fields can be jointly designed for new benchmarks of performance in restricted-slice and inner-volume excitations with the potential for enhanced imaging across a range of applications where fast image encoding of internal structures is the driving goal. A separate contribution involves fetal motion imaging measures for monitoring fetal health and neurological function. The group proposed a method for MRI fetal motion analysis using a deep pose estimator to extract quantitative metrics of motion. These tools enable the study of how fetal motion evolves with gestational age and maternal position.

Daniel G. Anderson, professor of chemical engineering, has continued his work in nanotherapeutics, biomaterials, and medical devices. This work has resulted in over 450 papers, patents, and patent applications. These advances have led to products that have been commercialized or are in clinical development. For example, he has developed "living therapeutics," which are human cell/material constructs capable of resisting rejection. These living therapeutics are being translated for the treatment of multiple diseases including hemophilia and diabetes in a collaboration between Eli Lilly and Sigilon Therapeutics, with multiple clinical trials planned for the coming year. His lab was also the first to use the CRISPR Cas9 system to treat a disease in an adult animal and continues to make important advances in non-viral systems capable of in vivo CRISPR genome editing. Technology from his laboratory has been licensed by CRISPR Therapeutics, a company that he helped found and that has begun the first company-sponsored CRISPR genome editing clinical trials for a human disease. More recently, he has been working to develop circular RNA as a human therapeutic. This has resulted in the formation of a new company, oRNA, that is seeking to advance this technology to the clinic. During the spring, Anderson taught two classes: 10.494 Integrated Chemical Engineering Topics III—a required senior design course for chemical engineering undergraduates that is focused on using chemical engineering principles to develop continuous nanoparticle manufacturing at pharmaceutical scale—and HST.500 Frontiers in Biomedical Engineering and Physics—a required core course that provides a framework for mapping research topics at the intersection of medicine and engineering/physics as well as training in scientific proposal writing, peer review, and communications.

Sangeeta Bhatia is the John J. and Dorothy Wilson Professor of Health Sciences and Technology and Electrical Engineering and Computer Science. To overcome the limitations involved with conventional imaging tests and endogenous biomarkers to detect cancers, Bhatia and her group engineered a new type of "synthetic" biomarker that combines several kinds of materials in a single test. Synthetic biomarkers are an approach to detecting tumors in which a particle is introduced that can then induce a signal from cancer cells that did not previously exist in the body. In this way biomarker signals are better able to stand out from the "noise" of background signals made by healthy cells, and, by depending on activation by enzymes present in a tumor environment, the signals can be amplified to be much stronger—together resulting in a diagnostic tool that is both sensitive and specific. Previously the group's synthetic biomarkers were detected in urine signals and even exhaled in breath. However, the piece that was missing was to find where in the body these biomarkers are produced. To close this gap, the group engineered protease-responsive imaging sensors for malignancy to combine the targeted delivery of activity-driven synthetic biomarkers with the capacity to be "loaded on demand" to create a positron emission tomography/computed tomography imaging agent for both in situ and noninvasive disease visualization and monitoring. They compared tumor acidosis-mediated imaging against a standard, clinically used imaging tracer and demonstrated long-term monitoring of cancer progression and regression in two models of metastatic colorectal cancer with and without treatment by a first-line chemotherapy drug. Providing both tools in a single injection may shorten the regulatory path to bringing a new medicine to patients and also offers a tool that can help clinicians decide between possible treatment options, even when monitoring for drug response or watching for a post-surgical relapse. This work was featured in MIT News and was recently published in *Nature Nanotechnology*.

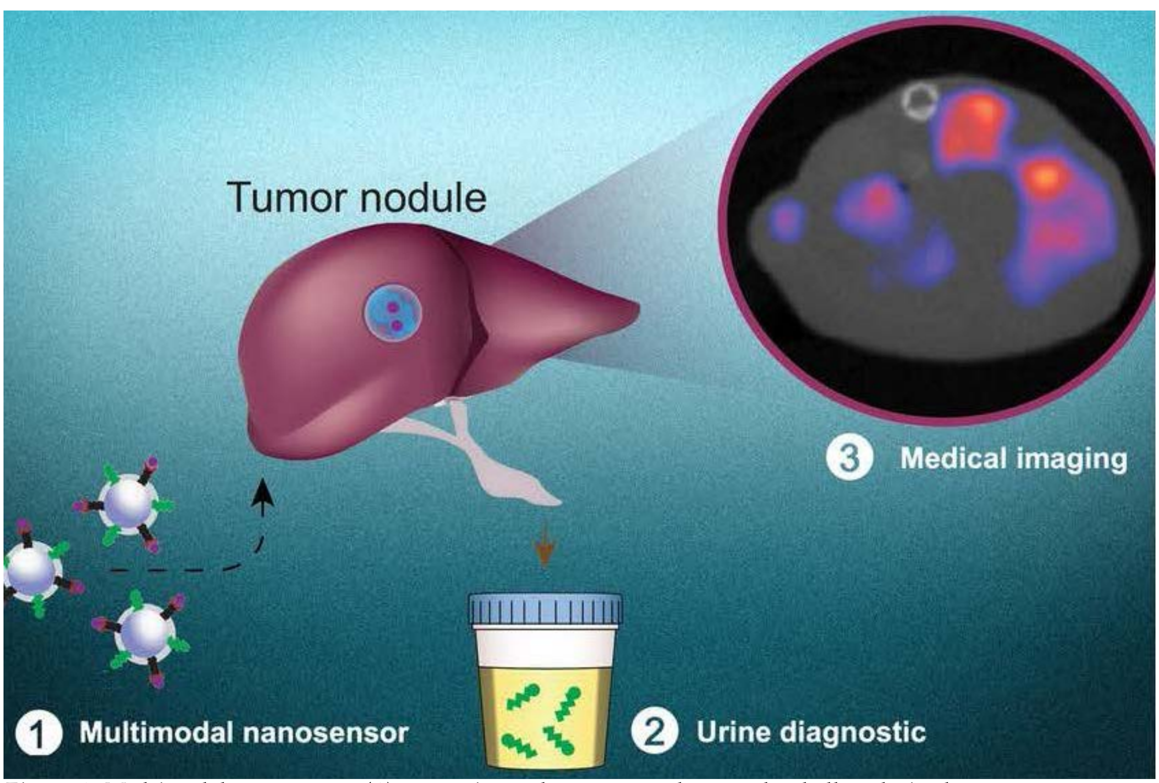

Figure 1. Multimodal nanosensors (1) are engineered to target and respond to hallmarks in the tumor microenvironment. The nanosensors provide both a noninvasive urinary monitoring tool (2) and an on-demand medical imaging agent (3) to localize tumor metastasis and assess response to therapy.

In addition, Bhatia worked with Susan Hockfield and Nancy Hopkins to publish a special report in the MIT Faculty Newsletter regarding their collaborative study with the Boston Biotech Working Group (BBWG) and the Sloan Foundation, in which they quantified that fewer women than men faculty at MIT move their research discoveries into companies, and fewer serve as scientific advisers or on boards of directors. This lost opportunity was proposed to represent a pool of 40 "missing" biotech companies that could otherwise be contributing jobs, revenue, and medicines to the world at large. Importantly, Bhatia and her colleagues emphasized that there are differences between the per capita rates of company founding patterns by female faculty across departments, namely that the engineering departments studied exhibit company founding trends that are aligned with the representation of female faculty within the departments, whereas female faculty are at a distinctly larger disadvantage in other science departments. Based on these observations, Bhatia has co-launched a Future Founders bootcamp program to provide real-world training and support for female faculty interested in learning how to launch companies. She has also spearheaded "VC Pledge," a campaign championed by the BBWG that invites venture capital groups to commit to achieving, within two years, a goal of at least 25% women on the boards of companies they influence. A summary of this effort was published in an editorial titled "Opening a Path to Biotech" in *Science* earlier this year.

Over the past year, Emery Brown and his group developed a machine learning algorithm that can accurately predict the state of unconsciousness maintained by GABAergic anesthetics from electroencephalogram spectral features. Their results, which were published in *PLoS One*, hold promise for the design of decision aids that anesthesiologists can use in real time to track unconsciousness and for the creation of closed loop anesthesia delivery systems. They also established that electrodermal activity can be accurately described through a physiologically based inverse Gaussian statistical model. This research holds promise for characterizing nociception (pain) and for developing real-time strategies for tracking nociception in patients under general anesthesia. In addition, the group completed detailed studies of the unconscious state maintained by propofol in a non-human primate model. During propofol-maintained unconsciousness, they recorded from the pre-frontal cortex, the superior temporal gyrus, the posterior parietal cortex, and the central thalamus. They identified two significant features of unconsciousness maintained by propofol: large-scale inhibition of neural spiking across the entire brain and synchronous activity in local field potentials across all four areas. They also demonstrated that arousal could be immediately restored by stimulating the central thalamus. This work was published in *eLife.*

Arup K. Chakraborty, the Robert T. Haslam (1911) Professor in Chemical Engineering, continued efforts to understand the mechanistic bases of how a systemic immune response to pathogens arises and how its aberrant regulation leads to disease. Research aimed at understanding how this knowledge can be harnessed for the rational design of vaccines and therapies is an important facet as well. Chakraborty, in collaboration with Phillip Sharp and Richard Young, also continued to work on a project initiated in 2016 on understanding how genes critical in maintaining healthy cell states are regulated. Chakraborty researched COVID-19 in 2020–2021, and his HIV work has led to an immunogenic vaccine in monkeys with efforts under way to move the concept to humans. In addition, Chakraborty published *Viruses, Pandemics, and Immunity*, a general audience book that has been well received.

Kwanghun Chung, associate professor of chemical engineering and of brain and cognitive sciences, continued to lead an interdisciplinary research team that seeks to develop and apply novel technologies for holistic understanding of large-scale complex biological systems. Recent research advances by the Chung lab include the development of technology that transforms human brain tissues into elastic hydrogels to enhance macromolecular accessibility and mechanical stability and technology that enables high-dimensional phenotyping of organoid disease models. He led several large projects, including a $9 million NIH human brain mapping project and a $5 million NIH reusable antibody development project, to apply his technologies for mapping and studying the human brain. In addition, his group has active collaborations with many researchers at MIT, the Broad Institute, MGH, and Harvard to study various neurological disorders such as autism spectrum disorder and Alzheimer's disease. During the past year, Professor Chung taught 10.302 Transport Processes and HST.562 Pioneering Technologies for Interrogating Complex Biological Systems. He also served on the IMES Committee for Academic Programs and the Department of Chemical Engineering graduate admission committee. In addition, he continued as a chief scientist with start-up LifeCanvas Technologies, which aims to advance the adoption and usage of the Chung lab's tissue molecular phenotyping technologies.

In fall 2020, Richard Cohen, the Whitaker Professor in Biomedical Engineering, focused his activity on supporting the Sloan Healthcare Certificate program by directing one of the program's elective courses (HST.973/15.124 Evaluating a Biomedical Business Concept). In addition, he served as one of two faculty members on the certificate program's board and advised students regarding their efforts to launch biomedical companies. Cohen began a one-year sabbatical leave at the beginning of calendar year 2021. He is researching materials for a book on hypothesis testing in medicine and biomedical entrepreneurship. Also, he has continued to work with Sirona Medical Technologies Inc. to develop a novel catheter technology for the treatment of life-threatening cardiac arrhythmias. This technology, which combines electrical mapping with focused radio frequency or pulsed field ablation, promises to improve both the efficacy and safety of this important and rapidly growing means of therapy. He also completed his service as an expert witness in a prominent corporate litigation case relating to commercialization of biomedical technology.

James J. Collins, the Termeer Professor of Medical Engineering and Science, continued to develop innovative synthetic biology platforms that can be used to address critical issues in medicine, biotechnology, and the life sciences. Notably, Collins has continued to focus his research program on addressing the COVID-19 pandemic. Along these lines, he demonstrated that his freeze-dried, cell-free synthetic biology platforms can be used to create COVID-19 face mask diagnostics. Specifically, Collins developed a face mask with a lyophilized CRISPR sensor for wearable, noninvasive detection of SARS-CoV-2 at room temperature within 90 minutes, requiring no user intervention other than the press of a button. More broadly, Collins designed and developed lightweight, flexible substrates and textiles functionalized with freeze-dried cell-free synthetic circuits, including CRISPR-based tools, that detect metabolites, chemicals, and pathogen nucleic acid signatures. These wearable devices are activated upon rehydration from aqueous exposure events and report the presence of specific molecular targets via colorimetric changes or an optical fiber network that detects fluorescent and luminescent outputs. The detection limits for nucleic acids rival current laboratory methods such as quantitative polymerase chain reaction. This work was published in *Nature Biotechnology* and received worldwide attention.

Elazer R. Edelman is the Edward J. Poitras Professor in Medical Engineering and Science. His research combines his scientific and medical training, integrating multiple disciplines. His research continues to focus on the applied and basic sciences of cardiovascular diseases. The work of his students and fellows has redefined the nature of critical diseases including aortic stenosis, atrial fibrillation, and coronary artery disease. On a basic level, his students have redefined the nature of endothelial cell heterogeneity and the paracrine regulation of complex diseases such as atherosclerosis and cancer. Edelman's laboratory has also focused on using advanced material science to explain unexpected failures in the most promising emerging medical devices. He and his group have published more than 20 papers over the past year.

John Gabrieli is the Grover Hermann Professor of Health Sciences and Technology. He and his group made progress on two major areas of mental health and brain development in children and adolescents. They completed the Human Connectome Project, the premier NIH study of the human brain. This multi-institutional project, which included Massachusetts General Hospital, Boston University, and McLean Hospital, was the largest study ever of the brain basis of adolescent anxiety and depression. They also published papers showing how mindfulness training in a Boston public school serving primarily children from lower-income families of color decreased stress and negative feelings and increased children's ability to sustain focused attention.

Lee Gehrke, Hermann L. F. von Helmholtz Professor of Health Sciences and Technology, is a molecular virologist who directs the HST human functional anatomy course at Harvard Medical School. He studies RNA viruses, including SARS-CoV-2, Zika, West Nile, dengue, and others. The Gehrke laboratory is funded by the National Institutes of Health to develop new experimental models to study infectious diseases. This work involves high containment (biosafety level 3) viruses and organoids derived from human cells. Gehrke has also been active in designing and building rapid diagnostic tests to detect viruses such as SARS-CoV-2, dengue, Zika, and chikungunya.

J. W. Kieckhefer Professor of Health Sciences and Technology Martha Gray leads the Biomedical Technology Innovation Group. Her research program focuses on formalizing approaches that drive innovation to create impact, particularly in the context of pre-doctoral and postdoctoral research training. The group's flagship program, the MIT Catalyst Program, has grown in its reach. Thanks to the group's partnership with the Veterans Health Administration, it now recruits nationally. At present, there are 20 Catalyst Fellows with translationally oriented projects. Also, the group supported the establishment of a sister program, Catalyst Europe. In the pilot offering, three new projects were nucleated, two of which led to collaborations with MIT researchers. Finally, with support from the Office of Experiential Learning, and in partnership with the Abdul Latif Jameel World Education Lab, the group created a program for undergraduates that included both an Undergraduate Research Opportunities Program experience with a Catalyst project and a companion longitudinal professional development experience. Of the approximately 15 undergraduate participants, several were first-year women students.

AY2021 marks the sixth year of the IMPACT program (and the conclusion of NIH support for the program). IMPACT is a supplementary mentoring program for postdocs and advanced graduate students that centers on enabling participants to consider and articulate explicitly the potential impact of their work. Additionally, it provides an opportunity to explore different career paths. Since its inception, 179 trainees (64% women, 24% members of underrepresented minority groups) have completed the program. Independent surveys conducted by the MIT Teaching and Learning Lab revealed that 94% of participants felt that it was an impactful experience, and 99% said they observed progress by other trainees. Given the program's success and its attractiveness to underrepresented groups, we are exploring alternative means of funding.

Thomas Heldt, associate professor of electrical engineering and computer science, directs the Integrative Neuromonitoring and Critical Care Informatics Group at IMES. Using physiologically based dynamic models, the group leverages multivariate bedside monitoring data—on the second to hour time scale—to understand the physiology of the injured brain, to improve diagnoses, and to accelerate treatment decisions for the critically ill. The group continues very strong and active collaborations with clinicians at Boston Children's Hospital, Boston Medical Center, Massachusetts General Hospital, and Beth Israel Deaconess Medical Center (BIDMC) in the areas of neurocritical and neonatal critical care as well as other areas of patient monitoring.

Adding to the group's growing research portfolio in neuromonitoring, Professor Heldt teamed up with Tamara Broderick and Vivienne Sze from MIT Lincoln Laboratory and US Air Force active-duty personnel to investigate the extent to which digital biomarkers—and particularly eye tracking metrics—can be used to improve and personalize pilot training. Initial results indicate clear and reproducible physiological responses to virtual reality–based simulated flying scenarios of varying degrees of difficulty. The team has also identified candidate gaze metrics that demonstrate appropriate and inappropriate responses to standard flying tasks, potentially pointing to physiological variables that could be incorporated into the standard evaluation repertoire to determine whether a pilot trainee is ready to advance to the next training level.

Additionally, the team has further developed its ultrasound-based techniques for neuromonitoring applications. One area of focus is the development of volumetric blood flow measurement methods for vessels supplying blood to the brain. Conventional ultrasound-based techniques obtain only estimates of blood flow velocity, which are an imperfect surrogate of the volume of blood flowing through a blood vessel per unit time. The team has also leveraged the blood flow measurements for noninvasive determination of intracranial elastance, an important measure of brain health. The techniques developed have progressed from validation in table-top models of blood flow to tests in healthy volunteers.

Tami Lieberman is the Herman L. F. von Helmholtz Career Development Assistant Professor and is a member of the Ragon Institute and the Broad Institute. Her group is developing unique sample sets and evolutionary inference methods to build a mechanistic understanding of microbial community assembly with a focus on human skin. This year, she was a recipient of the NIH Director's New Innovator Award, a generous award that will allow her to move quickly in new directions. Her group has submitted two manuscripts for publication reporting on the dynamics of bacterial evolution in human skin. Most recently, her group has developed a high-precision computational tool for classifying bacterial strains in DNA sequences from complex samples. This tool has many use cases, including leveraging publicly available metagenomic data to perform epidemiology and detecting commensal strains particularly well adapted to modern human microbiomes. This year, Lieberman has given remote seminars at Imperial College London, the University of Washington, and the University of California at Berkeley, among others. In addition, she has contributed to the Covid response by collaborating on a study tracking SARS-CoV-2 spread in the Boston area (published in *Science*) and initiating the development of the MIT PPE team (recognized with an MIT Excellence Award).

Roger G. Mark became a post-tenure professor in 2019. In the past year, he taught one course: 6.022J/HST.542J Quantitative Systems Physiology, which enrolls undergraduates and early graduate students from multiple engineering departments. His laboratory's objectives are to improve health care through the generation of new clinical knowledge and new monitoring technology and to enhance decision support through the application of data science and machine learning technology to large collections of critical care data. His lab developed the widely used Medical Information Mart for Intensive Care database, which is freely available to more than 26,000 credentialed investigators worldwide. The lab also developed and supports PhysioNet, an extensive open archive of physiological signals. In terms of administrative and service responsibilities, Mark is chair of the MEMP Board of Advisors, a member of the HST-IMES Committee on Academic Programs and the Qualifying Exam in HST Committee, a MEMP faculty advisor, and a Department of Electrical Engineering and Computer Science (EECS) graduate student counselor.

Leonid Mirny is leading a research program aimed at understanding the organization of the human genome in 3D. He is a co-director of the Center for 3D Structure and Physics of the Genome, funded by the NIH 4D Nucleome Program. In the last year, the Mirny lab has published several high-profile papers in *Nature, Cell, eLife,* the *Proceedings of the National Academy of Sciences*, and other journals offering new insights into 3D genome organization. The main achievement of the lab in recent years was the theoretical prediction that the genome is folded by a novel mechanism of loop extrusion. Recent experimental studies have provided strong support for the proposed mechanism, leading to a true paradigm shift in the field of chromosome biology. Mirny continues to explore the physical mechanisms underlying the folding and function of the genome and their role in health and human diseases. He teaches the HST.508 Evolutionary and Quantitative Genomics and 8.592 Statistical Physics in Biology graduate classes and the HST.A01 Quantitative Biology Freshman Seminar, in which students learn genomics concepts through interactive games and table-top experiments.

W.M. Keck Career Development Professor Ellen Roche started her laboratory at IMES in September 2017. She has a dual appointment (Mechanical Engineering and IMES) and works on the design of innovative therapeutic devices and their enabling technologies. Research in Professor Roche's lab is focused on the design and development of implantable medical devices that augment native organ function, borrowing principles from nature to enhance their architecture and performance. Her work is broadly categorized into global mechanical assist and repair devices, localized smart therapy delivery devices, and enhanced preclinical and computational test model development with the ultimate goal of translating therapies into the clinical arena. Since starting her laboratory, she has published in *Nature Biomedical Engineering*, *Science Translational Medicine*, *Science Robotics*, the *Annals of Biomedical Engineering*, *Advanced Healthcare Materials*, *Advanced Science*, and other journals. She has been granted patents on a cardiac assist device and a light-reflecting catheter technology, and she has licensed a catheter-based technology to a Paris-based start-up.

There is a pressing need to understand the pathogenesis of SARS-CoV-2, which causes the disease COVID-19. This year Alex Shalek's lab, in collaboration with several researchers around the world, leveraged single-cell/nucleus RNA sequencing, highly multiplexed spatial imaging, flow cytometry, and other methods to define the primary cellular targets of SARS-CoV-2 and how COVID-19 impacts respiratory tissues. In one study, by examining cells collected from nasopharyngeal swabs, they discovered that COVID-19 dramatically alters the composition of the nasal epithelia and that individuals who go on to have more severe disease display early defects in intrinsic epithelial antiviral responses. In another study, by characterizing autopsy donor tissue samples, they similarly uncovered substantial remodeling of the lung epithelial, immune, and stromal compartments in severe disease, with evidence of multiple failed attempts at epithelial tissue regeneration. In both investigations, they resolved cells harboring viral transcripts and identified genes likely involved in susceptibility, resistance, or infection response. Collectively, these and related studies reveal detrimental as well as protective cell- and tissue-level responses to SARS-CoV-2. Furthermore, they suggest that failed epithelial cell behaviors may underlie and predict severe COVID-19.

In parallel, through local, national, and international partnerships, the Shalek lab pursued deep, mechanistic inquiry to elucidate the cellular and molecular features that inform tissue-level function and dysfunction across the spectrum of human health and disease to aid in the design of therapeutic and prophylactic interventions to improve human health.

The vision of the MIT Medical Electronic Device Realization Center (MEDRC), co-directed by Professor Charles Sodini, is to revolutionize medical diagnostics and treatments by bringing health care directly to the individual and to create enabling technology for the future information-driven health care system. Launched in May 2011, MEDRC currently has four member companies (Analog Devices, IBM, Nihon Kohden, Philips Research) at a funding level of approximately $1.5 million per year. MEDRC serves as a focal point for engagement with researchers across MIT, the medical device and microelectronics industries, venture-funded start-ups, and the Boston medical community. The MEDRC companies strongly support the newly formed IMES Industrial Group to broaden industry participation with IMES faculty and students.

Von Helmholtz Professor of Medical Engineering David Sontag's research focuses on machine learning in health care. Highlights over the past year include a new algorithm for disease progression modeling in multiple myeloma, an automated method of extracting the rationale for treatment discontinuation from clinical notes (with Memorial Sloan Kettering), a new deep learning algorithm for longitudinal health data, and a machine learning method that learns when to make a prediction versus defer to a human expert. Professor Sontag's collaboration with Mass General Brigham culminated in the publishing of a new decision support tool for antibiotic prescribing in uncomplicated urinary tract infections. Finally, Sontag's J-Clinic project, together with David Karger from EECS and the Beth Israel Deaconess Medical Center, led to a new AI-driven clinical documentation system that was piloted in early 2020 and has already been used, at the point of care, with over 1,000 patients. This past year, Sontag served as the program chair and then the general chair of the Conference on Uncertainty in Artificial Intelligence.

Research in Professor Collin Stultz's Computational Cardiovascular Research Group is focused on the development and application of machine learning methods that can inform and guide clinical decision making. Recently the group has developed an approach to identify patients with aortic stenosis who are at high risk of death within five years after diagnosis (the method has been implemented online and made available to the medical community at large), created a novel method for predicting the individualized effect of a given treatment on a patient, and developed and implemented methods for estimating cardiac pressures (which are typically measured using invasive procedures) from electrocardiograms alone.

Affiliate Faculty

Regina Barzila is a School of Engineering Distinguished Professor for AI and Health in the Department of Electrical Engineering and Computer Science and a member of the Computer Science and Artificial Intelligence Laboratory (CSAIL). She is also an AI faculty lead at the Jameel Clinic. Her research interests are in natural language processing and applications of deep learning to chemistry and oncology.

This year, Barzilay and her team focused on two areas of clinical AI: risk assessment and drug discovery. The group demonstrated that their model for predicting breast cancer sustains high accuracy across multiple populations, and they developed a new model for predicting future risk of lung cancer that achieves significant gains over currently used clinical models. In addition, they have developed a new algorithm for identifying combination therapies and demonstrated the potency of the therapies with Covid antivirals and chemotherapy drugs for pancreatic cancer.

Professor of dermatology Brett Bouma's research focuses on the development of new instrumentation and methods for imaging and characterizing the microstructural properties of biological tissues. The work ranges from investigating the physics of light-tissue interactions and innovating new optical technology to developing and translating novel instruments into clinical applications in cardiovascular, ophthalmic, and gastrointestinal imaging. His group has previously shown that polarimetry can be used to map the distribution of muscle and collagen in biological samples. Recently the group reported on the first in-human use of intravascular polarimetry to locate and characterize arterial disease in the coronary arteries with a miniature (0.8-mm-diameter) catheter. His team has extended their work to uncover the orientation of muscle and collagen fibers and has shown how remodeled coronary plaque can result in layers of disoriented fibers. Furthermore, his group has recently shown that polarimetry reveals unique signatures of coronary thrombus in patients with acute coronary syndrome. In order to develop even smaller diameter, flexible catheters on a size scale finer than a human hair, Bouma's group has been investigating novel methods in computational imaging with random encoding patterns obtained by scattering light in complex media. His group has recently demonstrated axial ranging, with a resolution approaching 10 μm and a depth range beyond 1 cm, using the interference of light arising through propagation in multi-mode optical fibers.

Associate Professor Lydia Bourouiba directs the Fluid Dynamics of Disease Transmission Laboratory. Her group's research leverages advanced fluid dynamic experiments at various scales, biophysical concepts, and mathematical modeling to understand the fundamental physical mechanisms shaping epidemiology and disease transmission dynamics in human, animal, and plant populations. Through detailed experiments and modeling, her work elucidates the multi-scale dynamics of fluid fragmentation, with a particular focus on the mixing, transport, and persistence of pathogens relevant to contamination and health.

Over the past year, Bourouiba's research and outreach efforts have focused primarily on communicating the role of airborne disease transmission of the SARS-CoV-2 virus and educating clinical, research, and lay audiences on the latest research results to help shape the public health response during the pandemic. She has published a series of definitive papers, in both the leading medical/clinical and basic science journals, on the fluid dynamics of respiratory infectious disease transmission, collectively cited over 1,500 times since the beginning of the COVID-19 pandemic. Her leadership in bringing multidisciplinary teams together to study host-to-host disease transmission mechanisms has been recognized with a dedicated Gordon Research Conference on Fluids and Health that she will lead in 2022.

In collaboration with colleagues at MGH, Henry Ellis Warren (1894) Professor Polina Golland and her group aim to develop methods that will enable application of computational analysis pipelines to severely undersampled MRI scans typically acquired as part of the clinical practice. Their approach is to generate anatomically plausible high-resolution images that are consistent with clinical scans and can be analyzed by standard software. Professor Golland and her collaborators use machine learning to build a model of anatomical variability from a large collection of clinical images and to fill in the missing values in these images. This work promises to enable computational analysis of the vast image collections accumulated by hospitals as part of their routine imaging. The resulting insights will illuminate disease effects on anatomy and physiology from very large patient cohorts. This research is supported by the NIH Neuroimaging Analysis Center.

In 2020–2021, Robert Langer, the David H. Koch (1962) Institute Professor, published 32 papers and delivered numerous lectures. He also served on seven Institute boards and a number of industry boards. Langer serves as a consultant to the following government agencies: the US State Department (science envoy), the National Academy of Sciences, the National Academy of Engineering, the National Academy of Inventors, the National Academy of Medicine, and the US Food and Drug Administration.

Dava Newman is the Apollo Professor of Astronautics and Engineering Systems. Working with two Draper Fellows, Tom Abitante and Rachel Bellisle, Newman's research program includes the Auroral Emission Radio Observer (AERO) CubeSat project (MIT-

Portugal Program), the AI Accelerator (US Air Force and MIT), the Resource Exploration and Science of Our Cosmic Environment (RESOURCE) project (funded by NASA), and the Earth Intelligence Engine for Weather and Climate (Lincoln Laboratory).

Recent recognition that liquid-liquid phase transitions in cells can concentrate factors into membraneless bodies in cells and that RNA is frequently a component of these assemblies stimulated speculation that super-enhancers (SEs) might be a manifestation of such phenomena. Richard Young introduced the concept of SEs as large regions of DNA bound by transcription factors that dramatically stimulate transcription from proximal promoters. Furthermore, he showed that SE-associated genes are frequently critical for normal development and that new SEs appear near many disease genes. Given that phase transitions can concentrate factors in a highly cooperative fashion to enhance the rate of reactions, the groups of Institute Professor Phillip A. Sharp, Young, and Arup Chakraborty conjectured that SEs function as a large membraneless assembly of factors that enhance the rate of transcription from adjacent promoters. They developed a model of phase transitions that illustrates their high dependence on valences and low dependence on affinity. They went on to demonstrate that SEs associated with specific genes have dynamic properties of condensates formed by liquid-liquid phase transitions. Recently, they showed that some well-known drugs are concentrated in specific condensates, indicating a possible opportunity to target agents within cells. Moreover, condensates are dynamic, and components such as RNA can nucleate a bi-molecular condensate and then, when produced in excess, disassociate it.

Professor of computer science and engineering Peter Szolovits and his research group work on the application of artificial intelligence methods to problems associated with clinical medicine. This includes machine learning from large collections of clinical data to build predictive models that may be useful in clinical decision support; multimodal representation learning to identify useful features from lab data, medications, diagnoses and procedures, images, and genomic data to improve predictions; and natural language processing to unlock the information in clinical notes. Another focus is how to incorporate a priori knowledge into machine learning models. Many conference papers and journal articles have been published as a result of the group's work. Professor Szolovits serves as the overall MIT principal investigator in a medical collaboration between Philips and MIT and also collaborates with colleagues at IBM, Takeda, Wistron, Bayer, MGH, Northwestern University, the Tufts Medical Center, Harvard Medical School, the University of Massachusetts Lowell, and George Mason University on a variety of projects.

Professors of the Practice

Joseph Frassica leads the Philips Research Americas laboratories. His research interests cover a broad range of topics including the use of high-resolution physiological data and clinical information to create predictors of patient trajectory in critical care, the development of new measurements for ultra-mobile ultrasound, and the application of artificial intelligence to predict the development of infectious diseases (including COVID-19) and detect early signs of toxic exposures in the environment.

Frassica continues to lead the MIT-Philips research alliance. To date, the program has yielded more than 20 high-quality joint studies between Philips Research and MIT faculty spanning a number of institutes including CSAIL, Lincoln Laboratory, IMES, EECS, and the Department of Mechanical Engineering. The alliance sponsors a clinical fellows program, with fellows representing the Langer lab, the McGovern Institute for Brain Research, the Sloan School of Management, IMES, MGH, BIDMC, and other groups.

Frassica's lab continues to work closely with Roger Mark and the Laboratory for Computational Physiology on projects aimed at uncovering new sources of big data for the development of AI for applications in health care. Last year, the joint project funded by the MIT-Philips research alliance posted more than 300,000 chest x-rays publicly for researchers around the world to use in AI projects related to diagnosis and treatment of diseases such as acute respiratory distress syndrome. This year we expect to release 200,000 additional records into the eICU Collaborative Research Database, which is hosted on PhysioNet.

In 2020, Professor Frassica's lab initiated a five-year program sponsored by the US Biomedical Advanced Research and Development Authority to develop an AI-driven multifunctional trauma ultrasound device for use in large-scale disasters. This device will enable field triage and diagnosis of multiple traumatic injuries to be conducted by paramedics and other disaster workers with minimal training.

In addition, the lab initiated two multi-year programs sponsored by the Department of Defense. The first program focuses on the prediction of the onset of infectious disease among healthy individuals and the second project is aimed at early detection of toxic exposures to dangerous agents such as narcotics and other potential toxins in operational environments.

Bruce D. Walker is director of the Ragon Institute of MGH, MIT and Harvard and a Howard Hughes Medical Institute investigator. He was appointed a professor of the practice in IMES in 2016. He is a member of IMES and the Department of Biology.

The overarching goal of the Walker laboratory is to define the interplay of immunologic, virologic, and host genetic factors that determine control of human viral infections as a means of guiding vaccine development and immunotherapeutic interventions. To address this goal, the lab focuses on HIV infection, an ongoing global epidemic with enormous medical, societal, and economic implications. A global solution requires an effective vaccine or a cure, both of which remain elusive. A fully preventive HIV vaccine will likely require induction of broadly neutralizing antibodies and effective T cell immunity, which have thus far defied induction by vaccination. However, optimism for vaccine-mediated control derives from infected individuals who maintain T cell–mediated HIV control without treatment, some for 35 years or more. Vaccines currently entering efficacy trials are unlikely to fully prevent infection but would represent a successful "functional cure" if they maintain viremia below this level. The Walker lab focuses on understanding this remarkable T cell–mediated control of HIV, building on successive discoveries from studying immunology in HIV-infected individuals.

During the past year the Walker lab has leveraged extensive investments in unique patient cohorts, collaborative networks in Africa, and investments in new research facilities to define mechanisms of immune control, immune failure, and immune enhancement in infected persons. Walker and his Ragon Institute collaborators have recently defined the basis for the ability of a small subset of HIV-infected individuals to maintain undetectable viremia for decades without the need for medications, namely via cytotoxic T cell–mediated elimination of all reservoir cells other than full-length proviruses integrated into deeply latent sites in the host chromosome. With the onset of the COVID-19 pandemic, Walker assumed joint faculty leadership of a new initiative, the Massachusetts Consortium for Pathogen Readiness, consisting of 500 scientists and clinicians from 20 institutions including all Massachusetts medical schools and teaching hospitals as well as the state department of health. As part of this effort, he mobilized the development of a biorepository of specimens from COVID-19 patients that have been made broadly available.

Walker collaborates with Howard Heller to teach their highly popular HST.S46 Evolution of an Epidemic undergraduate course in South Africa during the January intersession. The class, sponsored in part by IMES, had to be held via Zoom this year and was expanded to focus not only on HIV but also on COVID-19. The class consisted of lectures and presentations as well as remote interactions with traditional healers, hospitals, and clinical research sites.

Events

Harvard-MIT Program in Health Sciences and Technology

Faculty Poster Session and Student Research Forum

Two of our annual events, the 2020 fall HST Faculty Poster Session and the 2021 spring HST Student Research Forum, were not held this academic year due to the COVID-19 pandemic. We look forward to hosting them both in the future.

Community Awards

HST has a long-standing tradition of conferring annual awards to recognize faculty, staff, and students for exemplary teaching, mentoring, and service. The selection process is organized by the students, making these awards particularly meaningful to recipients. For the second consecutive year, we adapted the community awards celebration to a virtual format consisting of a 50-minute video featuring statements from all of the nominators and award recipients. The video, accompanied by a well-attended live chat for members of the HST community, premiered on April 29.

Graduation

The 2021 HST graduation celebration took place as a virtual event on May 26. It began with an hourlong graduation video released on HST's YouTube channel, accompanied by a live chat for graduates, their families, and the HST community. The video included remarks by faculty leaders and a student speaker in addition to an individual vignette with slide show for each graduate who chose to participate. Following the video, all were invited to join graduation reception party rooms via Zoom, hosted by an assortment of faculty, staff, and alumni.

Community Building

In addition to coordinating formal virtual events such as the community awards and graduation, HST Academic Office staff continued to provide creative formats to build connections and maintain student community during the pandemic. These efforts included supporting the student government in planning virtual social and professional development events and launching New to MEMP (N2M), a new series of weekly virtual meetings for first-year MEMP PhD students that serves as an extension of orientation. The fall N2M topics included faculty research talks and sessions on finding a research lab and preparing external fellowship applications as well as presentations by MIT's conflict of interest officer and staff from the Institute Discrimination and Harassment Response Office. During the spring term, we continued to offer N2M less frequently in a combination of open office hours and informal mixers where more senior students gave advice to first-year MEMP PhD students.

Institute for Medical Engineering and Science

Distinguished Speaker Series

IMES modified the Distinguished Speaker Series beginning in AY2020. The new format includes two lectures. One lecture honors IMES founding director Arup Chakraborty and the other is the Judith Richter Lecture in Education, Science, and Peace. Both lectures were postponed due to the COVID-19 pandemic.

Faculty Lunch

IMES faculty established a new faculty lunch series. Each month, one IMES faculty member presents for 20 to 30 minutes on a topic of her or his choice (e.g., a recent research result or an idea for a new grant). The remaining time is left for discussion. The only requirement is that the topic be broadly accessible as there is such a diversity of backgrounds among the IMES faculty. The intent of the series is to build stronger ties while working remotely and to complement existing faculty meetings.

Elazer Edelman
Director