Institute for Medical Engineering and Science

MIT's Institute for Medical Engineering and Science (IMES) improves human health through science and engineering. Founded in 2012, and comprising almost 1,000 faculty, students, researchers, and staff, IMES carries on work that 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 healthcare 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 between MIT, Harvard University, 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's Longwood campus in Boston as one of the five medical societies at the Harvard Medical School. The program reports to the medical school's dean for medical education and the dean for graduate education.

Centers, Strategic Initiatives, and Accomplishments

IMES is home to three centers that extend resources to investigators and students.

- The Center for Translational Research, which includes a Living Lab Gateway and Human Subject Center, is a joint effort between IMES and the Vice President for Research to provide new resources for human subject research, medical device and diagnostic innovation, and data sciences. As part of the Human Subject Center, the Clinical Research Center, led by Professor Elazer Edelman, is a preclinical testing and consulting facility on the MIT campus that works closely with Beth Israel Deaconess Medical Center, Boston Children's Hospital, Brigham and Women's Hospital, and Massachusetts General Hospital (MGH).
- The Center for Microbiome Informatics and Therapeutics, directed by Professor Eric Alm and Professor Ramnik Xavier, brings together researchers and clinicians to improve human health by diagnosing, treating, and preventing diseases associated with the human microbiome.
- The Medical Electronic Device Realization Center (MEDRC), directed by Professor Charles Sodini, works with medical device companies, clinicians, and MIT researchers to transform the device industry, including wearables and minimally invasive monitoring, imaging, and portable laboratory instrumentation. IMES is developing the MEDRC framework to establish and launch the IMES Industrial Group in the fall of 2019.

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

- The MIT-Sekisui House Program is a collaboration between MIT, eSolutions Inc., and Sekisui House (one of Japan's largest home builders) for in-home wellness monitoring and early detection systems. The program will innovate to accelerate early detection system translation and stimulate market opportunities.
- IMES is a co-principal investigator of the Tufts University Clinical and Translational Science Institute, a member of the National Institutes of Health's Clinical and Translational Science Awards Program consortium. The Clinical and Translational Science Institute collaborates with IMES to uncover clinical insights that help fine-tune early device testing. The collaboration also works to design sequences of promising ideas so that they are more likely to become successful medical applications.
- One Brave Idea, a collaboration between Brigham and Women's Hospital, IMES faculty members, and other researchers, will pursue new biomarkers for atherosclerosis, the hardening of the arteries that kills about 500,000 people in the United States every year.
- IMES is creating opportunities to work closely with the Ragon Institute of MGH, MIT, and Harvard University, whose mission is to contribute to the accelerated discovery of an HIV/AIDS vaccine. Several IMES faculty members are associated with the Ragon Institute and are working to increase research collaborations. IMES doctoral students serve as teaching assistants for Ragon Director Bruce Walker's course, HST 434 Evolution of an Epidemic in South Africa, sponsored in part by IMES.
- MGH is a key strategic partner of IMES in many spheres. Through this partnership, IMES and MGH pursue projects that are 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 problems 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. MIT linQ's portfolio of international innovation programs includes Catalyst (a fellowship program), IMPACT (a mentorship program), and IDEA2 Global (a training and mentoring program). As an example, Catalyst has been extraordinarily successful in serving as a nucleus for high-impact projects, many of which have garnered private investment after three to five years of research at MIT, and in providing a unique training experience that accelerates the careers of researchers.
- IMES has an active collaboration with the Institut Químic de Sarrià (IQS) in Barcelona called the MIT-Spain Program. IMES is expanding and formalizing the collaboration to include bidirectional exchange of faculty and students to promote active research collaborations, joint design of an IMES–IQS certificate program, and development of sponsored research agreements with industry partners.

- Miami-Dade County and IMES are collaborating to create a so-called high-tech concentrator to facilitate the development of new technologies in the healthcare industry and launch new innovation-driven enterprises that may come out of the work in this community. Dade County is a regional economic center that connects North and South America; IMES hopes to leverage this opportunity to extend collaborations into South America.

IMES's other key accomplishments include building the IMES community and its ties across MIT. Among other efforts, IMES implemented awarding a certificate of completion for postdoctoral scholars at the end of their appointment in IMES. This effort will recognize the contributions of the scholars and create *esprit de corps* among them for continued involvement in IMES.

IMES is modifying the Distinguished Speaker Series beginning in AY2020. The new format will include two lectures. One lecture will honor IMES's founding director, Arup Chakraborty. The second lecture will be the Judith Richter Lecture in Education, Science, and Peace (some $600,000 was raised to support this latter lectureship). In addition, there will be an award to celebrate an emerging female star in science. A committee with members across MIT will select the lecturers and awardees.

Resource Development

Maura Ridge joined IMES in January 2019 as the new leadership giving officer. Department development efforts will happen in close collaboration with the administrative officer and extend to individual fundraising and industry relations. Reporting jointly to the director of IMES and the School of Engineering's assistant dean for development, the leadership giving officer will create and execute a comprehensive, strategic development plan that is designed to raise awareness, strengthen relationships, and garner financial support for IMES initiatives and academic programs.

In June, IMES secured a $13.5 million commitment from Sekisui House. Part of this gift, $6 million, will fund capital renovations of portions of the first and second floors of Building E25 to create the new Living Lab Gateway. The remaining $7.5 million, to be paid over five years, is to sponsor research for the new Sekisui House at MIT program, to be housed in the Living Lab. The Sekisui House at MIT space will be outfitted with embedded sensors for oversensing low-profile, ambient signals, gold standard diagnostics, and high-precision, research-grade sensors for establishing diagnostic targets and base truth. The program will enhance the education, research, and innovation mission of MIT in the broad area of ambient environment health and wellness monitoring and early detection systems. IMES is excited about this multi-year collaboration with Sekisui House, as well as the new Living Lab.

IMES also secured a gift of $600,000 from Judith Richter, a successful entrepreneur and philanthropist in Israel. She is a founder of the NIR School of the Heart, a comprehensive experiential program aimed at enriching the academic, cultural, social, and personal development of promising teenagers throughout the Middle East. Richter's gift will provide funding for a new lecture in education, science, and peace; fellowship support with preference for a student from Israel; and a prestigious new award recognizing upcoming female researchers.

IMES is working to establish closer relationships with the Kendall Square ecosystem. Under the direction of Professor Charles Sodini, IMES did preliminary work in FY2019 to create a new IMES Industrial Group (IIG). The IIG will educate, inspire, and ignite conversations between MIT faculty and students and industry representatives about mutually important issues and research areas. Benefits of membership in the IIG include attendance for company representatives at biannual symposia and student poster sessions, opportunities to build relationships with IMES students and provide mentorship or internship opportunities, and opportunities to interact with IMES faculty and discuss mutual research interests, perhaps leading to collaborative research projects. The first IIG symposium will be held in October 2019.

Academic Program

HST is among the largest biomedical engineering and physician scientist training programs in the US, with 305 students enrolled in its graduate degree programs during AY2019. There were 115 Medical Engineering and Medical Physics (MEMP) PhD students, including three students who were also pursuing an MD degree, and 193 MD and MD-PhD students (including the three MEMP-MD students). HST graduate students work with faculty members from MIT, Harvard University, 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 at MIT, 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 six years, and in some cases also pursue an MD. MEMP students are extremely successful in obtaining outside funding support for their graduate studies, with 25% of MEMP students holding external fellowships in AY2019.

Two specialized programs within MEMP are the Neuroimaging Training Program and the Mentored Research Program in Bioastronautics. The Neuroimaging Training Program is supported by a training grant from the National Institute of Biomedical Imaging and Bioengineering. Professors Bruce Rosen and Randy Gollub—both members of the HST faculty based at the Martinos Center at MGH—co-direct the program. Trainees are identified from among those already enrolled in MEMP who have 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 with related research interests.

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

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

Graduate Education in Medical Sciences Certificate Program

Graduate Education in Medical Sciences (GEMS) is a certificate program open to doctoral students in MIT's School of Engineering and School of Science who are interested in working at the intersection of engineering, science, 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 student's pursuit of a PhD. In addition to coursework in pathology and pathophysiology, participants attend seminars with HST students and engage in an individually tailored clinical experience. 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 founded with support from a Howard Hughes Medical Institute 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 Howard Hughes Medical Institute funding ended, was revitalized after the founding of IMES. Since 2012, 32 new students have enrolled in GEMS, 11 of those in AY2019.

Summer Institute

Patterned after MIT's Summer Research Program, HST offers a specialized Summer Institute Program in Biomedical Optics, offered in collaboration with the Wellman Center for Photomedicine at MGH. Thirty-seven students are enrolled in summer 2019.

This program offers a unique opportunity for outstanding undergraduate college students considering a career in biomedical engineering, medical science, or both. Through hands-on research and in-depth lectures, participants learn about either biomedical optics or bioinformatics and engage in the application of these fields to solving problems in human health. 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 build strong, enduring connections with faculty working in the field.

Honors and Awards

Faculty Honors and Promotions

Sangeeta Bhatia received a seven-year renewal of Howard Hughes Medical Institute Investigator status, was elected to the Brown University Board of Fellows, and received the Othmer Gold Medal from the Science History Institute. She also received a DSc (Medicine) degree, *honoris causa*, from the University of London Institute of Cancer Research.

Lydia Bourouiba was promoted to associate professor, Department of Civil and Environmental Engineering and IMES.

Emery Brown was elected to the State of Florida Inventors Hall of Fame; received the Dickson Prize for Science from Carnegie Mellon University, Pittsburgh, PA; and received a DSc degree, *honoris causa*, from the University of Southern California, Los Angeles, CA. He was also elected to the board of trustees of the John Simon Guggenheim Memorial Foundation.

Arup Chakraborty was awarded an honorary doctorate by the Hong Kong University of Science and Technology.

Kwanghun Chung was promoted to associate professor, Department of Chemical Engineering and IMES, and received the Presidential Early Career Award for Scientists and Engineers. He also received the Association of Korean Neuroscientists Junior Faculty Award.

James J. Collins was elected fellow of the World Academy of Sciences, received the Pierre Galletti Award from the American Institute for Medical and Biological Engineering, and was included in the Healthcare and Life Sciences 50 in *Irish America* magazine. He was named co-faculty lead of MIT's recent J-Clinics initiative in digital health, which seeks to galvanize campus activities and external collaborations in this area.

Elazer R. Edelman was a Biomedical Research Day Honoree (Investigator) in October 2018 at the Massachusetts Society for Medical Research; he received an official citation from the State Senate, Commonwealth of Massachusetts, and one from the House of Representatives, Commonwealth of Massachusetts. He also received an Excellence in Mentoring Award, from the Corrigan Minehan Heart Center, MGH, in June 2019.

Thomas Heldt received the Burgess ('52) and Elizabeth Jamieson Award for Teaching Excellence, Department of Electrical Engineering and Computer Science (EECS).

Robert Langer received an honorary degree from Columbia University. He received the American Chemical Society Leadership Award for Historic Scientific Advancement, the Hope Funds for Cancer Award of Excellence in Basic Sciences, and the Dreyfus Prize in the Chemical Sciences. Professor Langer became an elected International Fellow of the Royal Society of Canada and was named one of five US science envoys for 2018.

Tami Lieberman received the Smith Family Award for Excellence in Biomedical Research.

Ellen Roche was appointed the W.M. Keck Career Development Professor starting in July 2019. She was also given a National Science Foundation CAREER award and a Charles H. Hood Award for Excellence in Child Health Research for her work on pediatric cardiac devices.

Alex K. Shalek was promoted to associate professor, Department of Chemistry and IMES, and became an Institute Member of the Broad Institute of MIT and Harvard. He was also selected as one of the 25 "voices" who will guide the next 25 years of immunology by *Immunity*.

David Sontag was promoted to associate professor with tenure and received the Burgess ('52) and Elizabeth Jamieson Award for Excellence in Teaching.

Leia Stirling was a 2019–2020 American Association for the Advancement of Science Leshner Leadership Institute Public Engagement Fellow. She received the 2018 Harvard-MIT Health Science and Technology Thomas A. McMahon Mentoring Award.

Collin Stultz is chairperson for the National Institutes of Health, National Heart, Lung, and Blood Institute, board of scientific counselors. He is a regular member of MSFD—the Molecular Structure and Function Study Section D.

Laurence Young serves NASA as a member of the NASA Innovative Advanced Concepts External Council and as the head of science education for NASA's Translational Research Institute for Space Health.

Principal Research Scientist Award

Mercedes Balcells-Camps, principal research scientist, received a 2019 MIT Excellence Award for "Advancing Inclusion and Global Perspectives."

Faculty Mentoring and Teaching Awards

Mary Bouxsein was honored with HST's Thomas A. McMahon Mentoring Award.

Lorelei Mucci was honored with HST's Seidman Prize for MD Research Mentorship.

Anna Rutherford and Sarah Flier were honored with HST's Irving M. London Teaching Award.

Peter Szolovits received the Burgess ('52) and Elizabeth Jamieson Award for Excellence in Teaching.

This year, on the basis of suggestions from faculty, students, and staff, HST inaugurated a new award named for Roger G. Mark, MD, PhD, distinguished professor in HST, on the occasion of his transition to professor post-tenure. Sabine Hildebrandt and Trudy Van Houten were honored with the Roger G. Mark Outstanding Service Award to Faculty or Staff.

In addition, HST Director's Awards recognized Dr. Jeffrey Drazen and Stephen Loring for their outstanding teaching contributions in HST.

Student Honors and Awards

American Association of Physicists in Medicine John R. Cameron Young Investigators Award
Avilash Cramer, MEMP

Athanasiou *Annals of Biomedical Emgineering* Student Award
Markus Horvath, MEMP
Claudia Varela, MEMP

Brigham and Women's Hospital Research Excellence Award
Andrew Nguyen, MD

Dana-Farber Cancer Institute/Boston Children's Hospital—
David G. Nathan Summer Fellowship
William Mannherz, MD
Emory Werner, MD

Friends of McGovern Fellowship
Marc-Joseph Antonini, MEMP

HMS—Henry Asbury Christian Award
Joyce Hwang, MD

HMS—Leon Resnick Memorial Prize
Rachel Wolfson, MD

HMS—Multiculturalism and Diversity Award
Jingyi Gong, MD

HMS—Seidman Prize for Outstanding HST Senior Medical Student Thesis
Diane Miao, MD

HMS–James Tolbert Shipley Prize
Diane Miao, MD

HMS—Soma Weiss Student Research Day Poster Award
Katherine Redfield Chan, MD
Constance Wu, MD (honorable mention)

HST—Martha Gray Prizes for Excellence in Research (HST Forum)
David "DJ" Bozym, MD
Sebastian Palacios, GEMS/EECS
Vicente Parot, MEMP
Katherine Redfield, MD
Roman Stolyarov, MEMP
Jeremiah Wala, MD/PhD

HST—Outstanding Teaching Award-Student
Thomas Howard, MD/PhD

HST—Roger G. Mark Outstanding Service Award-Student
Katherine Redfield Chan, MD

La Caixa Graduate Fellowship
Jon Arizti Sanz, MEMP

MIT—William Asbjornsen Albert Memorial Fellowship
Max Olender, GEMS/Mechanical Engineering

MIT—Bridge Builder Award
HST MEMP Student Diversity Ambassadors (Group)
Aditi Gupta, Lucy Hu, Christian Landeros, Erin Byrne Rousseau, and Claudia Varela

MIT—Graduate Women of Excellence
Claudia Varela, MEMP
Elise Wilcox, MEMP

MIT—John A. Lyons Fellowship
Josh Murdock, MEMP

MIT—UROP Outstanding Mentor—Graduate Student/Postdoctoral Associate
Angela G. Zhang, MD/PhD

MIT—Whitaker Health Sciences Fund Fellowship
Ang Cui, MEMP

MIT—Hugh Hampton Young Memorial Fellowship
Avilash Cramer, MEMP

National Defense Science and Engineering Graduate Fellowship
Allison Porter, MEMP

National Science Foundation Graduate Research Fellowship
Jordan Harrod, MEMP
Neha Kapate, MEMP
Rumya Raghavan, MEMP

Regeneron Prize for Creative Innovation
Clara Starkweather, MD

2019 Wellcome Photography Prize
Carly Ziegler, MD/PhD

Research Program

Core Faculty

Elfar Adalsteinsson: Magnetic resonance imaging (MRI) in pregnancy presents a variety of unmet clinical needs and opportunities for scientific discovery. However, the application of current state-of-the-art hardware and software platforms and methods for MRI deliver unreliable and inferior image quality for mother and fetus compared with imaging in pediatrics and adults, primarily because of the severe and unpredictable motion by a noncompliant subject, the fetus. A dominant focus of Professor Adalsteinsson's current research is to improve the image quality and robustness of fetal MRI. His group is supported by the National Institutes of Health to develop, validate, and apply novel imaging methods in the fetus and placenta in close collaboration with other colleagues at MIT (Professors Golland, White, and Daniel), at the MGH Martinos Center (Professors Wald and Setsompop), and Boston Children's Hospital (Professors Grant and Gagoski). Another active domain of research is the design of algorithms and hardware for optimization of radio frequency transmission and main magnetic fields that stand to offer improved image quality for fast imaging and novel applications, including body imaging and fetal MRI. This effort is highly collaborative, with MGH Martinos Center and EECS colleagues.

Daniel G. Anderson: Professor Anderson continues his work in the field of nanotherapeutics, biomaterials, and medical devices. This work has led to the publication of more than 400 papers, patents, and patent applications, leading to products that have been commercialized or are in clinical development. For example, a therapeutic mRNA nanoformulation based on Anderson's work at MIT was licensed by Translate Bio and was cleared by the US Food and Drug Administration this year to begin human dosing as a therapy for genetic disorders of ornathine transcarbamasalyse. He has also developed so-called living therapeutics, which are human cell–material constructs capable of resisting rejection. These are being translated for the treatment of multiple diseases, including hemophilia and diabetes, in a collaboration between Eli Lilly and Sigilon Therapeutics. Clinical trials are planned for next year. Anderson's 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, which this year began the first company-sponsored CRISPR genome editing clinical trial for a human disease.

Last spring, Anderson taught 10.494 Integrated Chemical Engineering Topics III, a required senior design course for undergraduates in chemical engineering focused on using chemical engineering principles toward the development of continuous nanoparticle manufacturing at pharmaceutical scale. He also taught HST 500 Frontiers in (Bio)Medical 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: Improved biomarkers are needed for prostate cancer, as the current gold standard biomarkers have poor predictive value. Tests for circulating prostate-specific antigen levels are susceptible to various noncancer comorbidities in the prostate and do not provide prognostic information; physical biopsies are invasive, must be performed repeatedly, and sample only a fraction of the prostate. Injectable biosensors may provide a new paradigm for prostate cancer biomarkers by querying the status of the prostate via a noninvasive readout. Proteases are an important class of enzymes that play a role in every hallmark of cancer; their activities could be leveraged as biomarkers. Professor Bhatia's group identified a panel of prostate cancer proteases through transcriptomic and proteomic analysis. Using this panel, they developed a nanosensor library that measures protease activity in vitro using fluorescence and in vivo using urinary readouts. In xenograft mouse models, Professor Bhatia's group applied this nanosensor library to classify aggressive prostate cancer and to select predictive substrates. They also co-formulated a subset of nanosensors with integrin-targeting ligands to increase sensitivity. These targeted nanosensors robustly classified prostate cancer aggressiveness and outperformed prostate-specific antigen. This activity-based nanosensor library could be useful throughout clinical management of prostate cancer, with both diagnostic and prognostic utility.

Emery Brown: Clinicians have long had the goal of separating analgesia from anxiety when using deep brain electrical stimulation of the periaqueductal gray (PAG) to treat pain. Professor Brown's group has shown that selective activation of dopamine neurons within the PAG produces analgesia without other behavioral effects, while stimulating glutamate neurons mediates stress-induced anxiety and analgesia. His results suggest that dopamine agonists may represent a novel class of analgesic drugs and elucidate target neurons that could mediate their effect.

Anesthetics have profound effects on the brain and central nervous system. Vital signs, along with the electroencephalogram (EEG) and EEG-based indices, are commonly used to assess the brain states of patients receiving general anesthesia and sedation. Important information about the patient's arousal state during general anesthesia can also be obtained through use of the neurologic examination. This article reviews the main components of the neurologic examination, focusing primarily on the brainstem examination. It details the components of the brainstem examination that are most relevant for patient management during induction, maintenance, and emergence from general anesthesia. The examination is easy to apply and provides important complementary information about the patient's arousal level that cannot be discerned from vital signs and electroencephalogram measures.

Spectral properties of the EEG are commonly analyzed to characterize the brain's oscillatory properties in basic science and clinical neuroscience studies. The spectrum is a function that describes power as a function of frequency. To date inference procedures for spectra have focused on constructing confidence intervals at single frequencies using large sample-based analytic procedures or jackknife techniques. These procedures perform well when the frequencies of interest are chosen before the analysis. When these frequencies are chosen after some of the data have been analyzed, the validity of these conditional inferences is not addressed. If power at more than one frequency is investigated, corrections for multiple comparisons must also be incorporated. To develop a statistical inference approach that considers the spectrum as a function defined across frequencies, Brown's group combines multitaper spectral methods with a frequency-domain bootstrap (FDB) procedure. The multitaper method is optimal for minimizing the bias-variance tradeoff in spectral estimation. The FDB makes it possible to conduct Monte Carlo–based inferences for any part of the spectrum by drawing samples that respect the dependence structure in the EEG time series. His group showed that their multitaper FDB procedure performs well in simulation studies and in analyses comparing EEG recordings of children from two different age groups receiving general anesthesia.

Arup K. Chakraborty: Professor Chakraborty continued efforts to understand the mechanistic bases of how a specific and systemic immune response to pathogens occurs, and how its aberrant regulation leads to disease. Research aimed toward understanding how this knowledge can be harnessed for the rational design of vaccines and therapies is also an important facet. Chakraborty, in collaboration with Professors Sharp and Young, also continued to work on a project initiated in 2016 on understanding how genes critical for maintaining healthy cell states are regulated. Their latest collaboration on this subject, published in 2018, was listed as one of the top 10 breakthroughs of the year by *Science* magazine. Chakraborty is also working on two books on immunology, one for an audience of physical scientists who want to enter—or have entered—the field, and one for a general audience. Chakraborty continues to serve as a member of the US Defense Science Board and as a senior editor of *eLife.*

Kwanghun Chung: Professor Kwanghun Chung leads an interdisciplinary research team devoted to developing and applying novel technologies for holistic understanding of large-scale, complex biological systems. Recent research advances by the Chung Laboratory include the development of SHIELD (stabilization under harsh conditions via intramolecular epoxide linkages) technology that simultaneously and globally protects tissue physicochemical properties while allowing multiscale molecular imaging. The Chung Lab has expanded its two key technologies, SHEILD and eFLASH (electrophoretically driven fast labeling using affinity sweeping in hydrogel), for rapid and holistic phenotyping of complex biological systems. In addition, researchers have developed a technology platform to use three-dimensional (3-D) printing to produce synthetic vasculature networks and integrate them with organoids, "mini organs" produced in vitro using patient-derived, induced, pluripotent stem cells to address transport issue that limits the power of the organoid systems. The Chung Lab has openly shared the SHIELD reagents and protocols with more than 100 laboratories worldwide. The group has active collaborations with many researchers at MIT, the Broad Institute, MGH, and Harvard University. He has traveled extensively, including to the University of Washington, Stanford University, ETH Zurich, University of Laval, and Cold Harbor Asia, to speak about his group's technologies and their applications.

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, as well as the Chemical Engineering graduate admission and Brain and Cognitive Sciences graduate admission committees.

Richard Cohen: Professor Cohen focused his activity on supporting the Sloan Healthcare Certificate program and, more broadly, MIT's efforts in entrepreneurship. He directed one of the core courses (15.132/ HST.972 Medicine for Managers and Entrepreneurs Proseminar) and one of the elective courses (HST.973/15.124 Evaluating a Biomedical Business Concept) for the certificate program. He served as one of two faculty members on the certificate program's board. Cohen was also the faculty sponsor of the MIT Professional Education Short Program called "Organizations, Innovation, and Technology: Putting Ideas to Work." As co-founder and consultant, he worked with Sirona Medical Technologies, Inc., to develop a novel catheter technology for the treatment of life-threatening cardiac arrhythmias. This technology combines electrical mapping with focused radio frequency ablation and promises to improve both the efficacy and safety of this important and rapidly growing means of therapy. Cohen worked as a consultant with start-up company Osteoanalgesia, Inc., in the development of a novel anti-inflammatory drug for the treatment of rheumatoid arthritis and other inflammatory diseases. He also advised students on their efforts to launch biomedical companies.

James J. Collins: Termeer Professor of Medical Engineering and Science, Professor Collins continued to develop innovative synthetic biology platforms that can be used to address critical issues in medicine, biotechnology, and the life sciences. This past year, Professor Collins used freeze-dried, cell-free synthetic biology to create a rapid, low-cost research platform for analyzing gut microbiota and host biomarkers. The gut microbiome is an essential contributor to numerous processes in human health and disease. There is a growing need for research tools that can provide quick, affordable readouts of microbiome composition and activity. Microbiome studies currently rely on next-generation sequencing applications; however, the expensive, complex, and time-consuming nature of sequencing techniques has restricted large-scale, longitudinal studies and slowed efforts in basic research. To address the need for affordable, on demand, and simple analysis of microbiome samples, Collins advanced his freeze-dried, cell-free synthetic biology platform for use as a research tool to quantify bacterial and host ribonucleic acids (RNAs) from stool samples. It was demonstrated that the system can be used to rapidly and inexpensively detect and quantify species-specific messenger RNA (mRNA) from dozens of different gut bacteria, clinically relevant host biomarkers, and toxin mRNA in the diagnosis of *Clostridium difficile* infections. Collins' freeze-dried, cell-free platform is readily accessible to all researchers, providing rapid turn-around time, on-demand sample analysis, and simple data processing, unlike sequencing methods. Moreover, the approach offers a hundredfold cost savings over the reverse transcription polymerase chain reaction technique and is easily adaptable to a wide range of biological targets, including viruses, fungi, and eukaryotic nucleic acids.

Elazer Edelman: Professor Edelman's 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 such as aortic stenosis, atrial fibrillation, and coronary artery disease. Edelman's laboratory also focuses on using advanced material science to explain the unexpected failure of the most promising emerging medical devices. In 2018, Edelman and his group published some 21 critical papers; in the first half of 2019, they published 13 papers.

John Gabrieli: Professor Gabrieli's group made progress on two major areas of brain development in children—language and emotion. Back-and-forth verbal communications between parents and children have a great impact on children's language abilities and school readiness, and his group showed for the first time how parent-child communication at home influences the brain structure and function that underlie language ability in young children. With respect to emotion: there is a large increase in depression in adolescents in the United States. The Gabrieli group showed that brain measures in young children longitudinally predict the diagnosis of depression as these children grown into adolescents. Such knowledge could be used to promote early intervention to reduce the likelihood of developing depression.

Lee Gehrke: Professor Gehrke is a molecular virologist who directs the HST 010/011–FA 2020 Human Functional Anatomy course at Harvard Medical School. He studies RNA viruses, including the Zika virus, the West Nile virus, the Dengue virus, and others. The Gehrke laboratory has been active in designing and building rapid diagnostic tests to detect viruses in serum and urine. In collaboration with the laboratories of Rudolf Jaenisch and David Sabatini of the Whitehead Institute for Biomedical Research, the Gehrke laboratory is developing two- and three-dimensional tissue models for investigating neurotropic virus infections.

Martha Gray: Professor 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- and post-doctoral research training.

A key highlight for this year was the successful relaunch of the MIT Catalyst Program. Past editions of the program required the full-time, multiyear involvement of the program's fellows. The program consists of several phases: project definition (phase 1) and project execution (phase 2). The first phase, in particular, does not require full-time engagement. Thanks to partnerships with IMES, the US Department of Veterans Affairs, and a small pharmaceutical company, Professor Gray's group was able to recruit the fifth Catalyst cohort (the first one under the new structure). At the conclusion of this year, the program's fellows successfully defended a portfolio of research projects, each with evidence of potential impact. They are now preparing proposals to be submitted for funding, at which time they would progress to the second phase of the program.

Thomas Heldt: Professor Thomas Heldt directs the Integrative Neuromonitoring and Critical Care Informatics Group at IMES. Using physiologically based dynamic models, his group leverages multivariate bedside monitoring data—on the second-to-hour timescale—to understand the physiology of the injured brain, to improve diagnoses, and to accelerate treatment decisions in the critically ill. Professor Heldt's group continues very 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.

Over the past year, the collaboration between Professor Heldt's group and Dr. Robert Tasker (of Boston Children's Hospital) and Dr. James Holsapple (of Boston Medical Center) further validated the model-based, calibration-free, and noninvasive approach to continuous intracranial pressure estimation in a diverse set of patients ranging in age from two years old to more than 80 years old. The patients spanned a diverse set of etiologies, including traumatic brain injury, hydrocephalus, stroke, cerebrovascular malformations, and metabolic disorders. The estimates are essentially as accurate and as precise as the invasive measurement that requires drilling a hole into the patient's skull and advancing a catheter into the brain tissue or cerebrospinal fluid space. These results are being published in a series of manuscripts., with the first appearing in the *Journal of Neurosurgery:Pediatrics*.

In neuromonitoring research, Professor Heldt has teamed up with Professor Vivienne Sze of the Research Laboratory of Electronics and Professor Charles Sodini of IMES and the Microsystems Technology Laboratories to use cameras on consumer-grade electronic devices (smartphones and tablet computers) to measure features of eye movements. Such features have been shown to be affected in neurodegenerative diseases and may therefore serve as a digital biomarker of disease progression. With graduate students Gladynel Saavedra-Peña and Hsin-Yu Lai, Heldt and his group was able to demonstrate that features of interest could be recorded to clinical-grade accuracy. The researchers have recorded and analyzed more than 30,000 reactive eye movement tasks in healthy volunteers for comparison and exploratory data analysis. Heldt is currently in discussions with clinicians from the Memory Disorders Unit at MGH to translate his approach to clinical populations with mild cognitive impairment and early-stage Alzheimer's disease.

Tami Lieberman: Professor Lieberman started her group in January 2018 in the Department of Civil and Environmental Engineering and IMES as the Herman L. F. von Helmholtz Career Development Assistant Professor. She is also a member of the Ragon Institute and the Broad Institute. This year, her group continued to develop unique sample sets and evolutionary inference methods to build a mechanistic understanding of microbial community assembly on human skin. Data from a unique collaboration with families at Acera, a kindergarten-to-grade-eight private school, is pinpointing the key times at which members of the facial skin microbiome are acquired.

Professor Lieberman has won pilot grants for new work in colorectal cancer and in probiotic evolution within humans. This year, she gave seminars at Stanford University, the University of Michigan, Scripps, and in the United Kingdom, among other places, and traveled to consult for the Bill and Melinda Gates Foundation. She taught HST.508 Evolutionary Genetics and a new undergraduate course in the Department of Civil and Environmental Engineering, HST.538 Genomics and Evolution of Infectious Disease.

Roger G. Mark: In the past year, Professor Mark taught 6.022J/HST.542J Quantitative Systems Physiology, for undergraduates and early graduate students from multiple engineering departments, and HST.201 and HST.202 Introduction to Clinical Medicine and Medical Engineering I and II, for advanced MEMP students. His laboratory's objective is to improve health care through the generation of new clinical knowledge and new monitoring technology and decision support through the application of data science and machine-learning technology to large collections of critical care data. His laboratory has developed the widely used Medical Information Mart for Intensive Care database, which is freely available to more than 12,000 credentialed investigators worldwide. The laboratory also developed and supports PhysioNet, an extensive open archive of physiological signals. Professor Mark's administrative and service responsibilities include serving as chair of the MEMP board of advisors and a member of the HST-IMES Committee on Academic Programs and the MEMP Qualifying Examination in HST Committee. He is also a MEMP faculty advisor and EECS graduate student counselor.

Leonid Mirny: Professor Mirny is leading a research program aimed at understanding the organization of the human genome in three dimensions. He is a co-director of the Center for 3D Structure and Physics of the Genome, funded by the 4D Nucleome Program of the National Institutes of Health. In the past year, the Mirny Laboratory published several papers on three-dimensional genome organization, proposing and supporting a novel mechanism of genome organization by active loop extrusion. The most significant achievement of the past year was a study that established how active and inactive regions of the genome are segregated in space. To this end, the Mirny Lab has integrated microscopy and Hi-C data obtained by their collaborators for natural and engineered cells. (Hi-C is an extension of chromosome conformation capture, known as 3C.) Researchers found that spatial segregation of chromatin is akin to the phase separation in block copolymers and is driven by interactions between silent regions of the genome (heterochromatin). This study was published in *Nature*. Professor Mirny teaches the graduate subjects HST.508 Evolutionary and Quantitative Genomics, and 8.592 Statistical Physics in Biology, and a freshman seminar, HST.A01 Quantitative Biology—in which students learn the concepts of genomics through interactive games and tabletop experiments.

Ellen Roche: Professor Ellen Roche started her laboratory at IMES in August 2017. She has a joint appointment in Mechanical Engineering and IMES, and works on the design of innovative therapeutic devices and their enabling technologies. Research in Professor Roche's laboratory is focused on the design and development of implantable medical devices that augment or assist native function, borrowing principles from nature to design these devices. Her work is broadly categorized into mechanical assist and repair devices, biomaterial and therapy delivery devices, and enhanced pre-clinical and computational test model development, with the ultimate goal of translating enhanced therapeutic devices into the clinical arena. Professor Roche has published a number of papers since starting her laboratory.

Alex Shalek: Cellular immunity is critical for controlling intracellular pathogens, but individual cell dynamics and cell-to-cell cooperation in evolving human immune responses to infection have not been defined. This year, the Shalek Laboratory developed a broadly applicable, high-resolution method that couples single-cell RNA sequencing with strategies for unbiased gene-module discovery to uncover distinct sets of cells responding in concert to complex stimuli over time. In collaboration with the Walker Laboratory at the Ragon Institute and the Ndung'u Laboratory at the Africa Health Research Institute, researchers in Shalek's lab applied the method to profile—with unprecedented detail—the multicellular responses of four individuals pre- and immediately post-untreated human immunodeficiency virus 1 (HIV-1) infection, identifying key populations of cells with potential effects on the course of long-term infection. Onset of viremia induced a strong interferon response across multiple lymphocyte and myeloid lineages, followed by several cell-type-specific features including pro-inflammatory T-cell differentiation, prolonged monocyte major histocompatibility complex-II upregulation, and persistent natural killer cell cytolytic killing. Longitudinal sampling revealed alignment of distinct cell-type-specific gene programs with viral load over time, implicating key intra- and extracellular drivers that induce them. Two of the four participants studied developed spontaneous viral control at later time points. This was associated with elevated frequencies of proliferating cytotoxic cells immediately after infection, inclusive of a previously unappreciated proliferating natural killer cell subset. Overall, the team's study provides a unified framework for characterizing the evolution of cellular responses at single-cell resolution. The method's application to hyper-acute HIV-1 infection highlights the importance of monocytes and natural killer cells in driving response coordination and potentially influencing clinical trajectory, with prophylactic and therapeutic implications.

Charles Sodini: The vision of the MIT Medical Electronic Device Realization Center 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 healthcare system. Launched in May 2011, MEDRC currently has four member companies (Analog Devices, Nihon Kohden, Novartis, and Philips Research) supporting approximately 12 projects, with about 15 students and postdoctoral associates and eight principal investigators; MEDRC has funding of approximately $2 million annually. The center 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. Recently, Sodini has seen tremendous interest from the broader local industry, including biotechnology and pharmaceuticals. The companies supporting MEDRC also strongly support the formation of the IMES Industrial Group to broaden industry participation with IMES faculty and students. Over the past year, Professor Sodini has begun discussions and conducted feedback sessions to develop the framework for launching the IIG in the fall of 2019.

David Sontag: Professor Sontag made several new advances in artificial intelligence and statistics, specifically to causal inference from observational data, unsupervised learning, fairness of machine learning, few-shot learning, and approximate inference. Highlights include a published commentary in *Nature Medicine* on using off-policy reinforcement learning in health care, and a paper written with the MIT–IBM Watson Artificial Intelligence Laboratory on characterizing the region where new policies learned from causal inference can be safely used. In collaboration with Dr. Sanjat Kanjilal from MGH, Sontag showed that one can use predictions of antibiotic resistance to nearly eliminate second-line antibiotic use for uncomplicated urinary tract infections. With Dr. Steven Horng from Beth Israel Deaconess Medical Center, Sontag launched a new project on redesigning electronic medical records with seed funding from the MIT J-Clinic for Machine Learning in Health. Sontag continued to serve as the theme lead for healthcare in the MIT–IBM Watson Artificial Intelligence Laboratory, and also served on a subcommittee of Governor Baker's Mass Digital Health Council.

Collin Stultz: Research in the Computational Biophysics Group of the Research Laboratory of Electronics is focused on three areas: understanding conformational changes in biomolecules that play an important role in common human diseases, using machine learning to develop models that identify patients at high risk of adverse clinical events, and developing new methods to discover optimal treatment strategies for high-risk patients. The group uses an interdisciplinary approach combining computational modeling and machine learning to accomplish these tasks.

In recent years, Stultz's group has focused on using machine learning for patient risk stratification and clinical decision making. More generally, researchers are working with MGH collaborators to develop a MIT–MGH Center for Cardiovascular Engineering and Data Science for Personalized Medicine. The proposed center represents a combined effort between computer and data scientists at MIT and the division of cardiology at MGH. The work has been supported by the MIT J-Clinic and the MIT–IBM Watson Artificial Intelligence Laboratory.

Associate Faculty

Brett Bouma: Professor Bouma's research focuses on the development of new instrumentation and methods for imaging and characterizing the microstructural properties of biological tissues. The work starts with investigating the physics of light-tissue interactions—using Professor Bouma's group's findings as a basis for innovating new optical technology—and goes on to develop and translate novel instruments into clinical applications in cardiovascular, ophthalmic, and gastrointestinal imaging. Bouma's group has previously shown that polarimetry can be used to map the distribution of muscle and collagen in biological samples. In the past year, his team has extended their work to uncover the orientation of muscle and collagen fibers and have seen how remodeled coronary plaque can result in layers of disoriented fibers. He has applied this same approach to assess the structure of the retinal pigment epithelium. In the past year, Bouma concluded enrollment in the first human clinical pilot study to image the coronaries of patients undergoing cardiac catheterization and have demonstrated that polarimetry provides an unprecedented ability to characterize atherosclerotic plaque composition, including previously unseen features such as cholesterol crystals in vivo.

Lydia Bourouiba: This past year, the Bourouiba Laboratory published key papers revisiting canonical fluid dynamics problems of droplet formation. The findings are paving the way to new detection, tracking, and capturing tools of droplets formed from the breakup of contaminated fluids, with human health and food safety in mind. She continued to establish fundamental collaborations with the Centers for Disease Control and Prevention and local infection control teams, for example, a team at MGH. She launched and executed the first phase of the flu transmission study this past spring, with her team working closely with the MIT Clinical Research Center and MIT Medical and urgent care teams.

Polina Golland: In collaboration with colleagues at MGH, Professor Golland and her group aim to develop methods that will enable the application of computational analysis pipelines to severely under-sampled MRI scans that are typically acquired as part of clinical practice. Their approach is to generate a high-resolution, anatomically plausible volume that is consistent with the clinical scan, and can be analyzed by standard software, typically developed for such high-resolution research scans. Professor Golland and her collaborators use machine learning to build a model of anatomical variability from a large collection of clinical images and to employ such learning 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 routine imaging. The resulting insights will illuminate disease effects on anatomy and physiology from very large patient cohorts. This work is supported by the Neuroimage Analysis Center, a National Institute of Biomedical Imaging and Bioengineering P41 Biomedical Technology Resource Center under the National Institutes of Health.

Robert Langer: Professor Langer received honorary degrees from Columbia University, the University of Illinois, the University of Limerick (Ireland), and the University of Laval (Canada). He received the American Chemical Society Leadership Award for Historic Scientific Advancement, the Alpha Omega Dental Fraternity Achievement Medal Award, the Hope Funds for Cancer Award of Excellence in Basic Sciences, and the Dreyfus Prize in the Chemical Sciences. Professor Langer presented the Ference Jolsez Memorial Lecture (at the 12th Interventional MRI Symposium), as well as lectures for the New York Stem Cell Foundation Fellowship Alumni Meeting and the Broad Institute. He also spoke before the Netherlands Life Sciences and IVA Royal Swedish Academy of Engineering. He became an elected international fellow of the Royal Society of Canada and was named one of five US science envoys for 2018.

Phillip A. Sharp: 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 the speculation that so-called super enhancers might be a manifestation of these phenomena. Richard Young introduced the concept of super enhancers as large regions of DNA bound by transcription factors that dramatically stimulate transcription from proximal promoters. Further, he showed that genes associated with super enhancers are frequently critical for normal development and that new super enhancers appear near many disease genes. Given that phase transitions can concentrate factors in a highly cooperative fashion to enhance the rate of reactions, Professor Sharp's group conjectured that super enhancers function as a large membraneless assembly of factors that enhance the rate of transcription from adjacent promoters. In collaboration with the Chakraborty and Young Labs, Sharp developed a model of phase transitions that illustrated their high dependence on valences and low dependence on affinity and outlined how its properties are consistent with many of the known phenotypes of super enhancers. Over the past year, this team has shown that super enhancers associated with specific genes have dynamic properties of condensates formed by liquid-liquid phase transitions. Because these condensates are highly sensitive to drug inhibitors that reduce the valence of interactions between their constituents, this insight offers potential new opportunities to treat many diseases.

Leia Stirling: The aim of Professor Stirling's research is to quantify human performance and human machine fluency in operational settings by advancing the use of wearable sensors for space, medical, and military applications. Fluency is the well-synchronized meshing of actions between a human and a system, and is required for coordinated human-in-the-loop tasks. Quantifying these measures is key for augmenting human performance, mitigating injury risk, and providing relevant feedback to subject matter experts across many domains. Development of human-in-the-loop applications requires understanding the human capability to complete required tasks while utilizing additional technology, such as exosystems (rigid exoskeletons and soft exosuits). In many domains, human motor performance is assessed visually by subject matter experts, but what is needed is the capability to assess performance when direct visual assessment is not possible. Stirling enhances the ability to make decisions when the person is not observable (e.g., an astronaut in a spacesuit), the subject matter expert is not present (e.g., telehealth), or the action is fast (e.g., military readiness) by enabling wearable sensors to quantify these qualitative assessments. Wearable sensors passively sense information about humans or their environment; exosystems are technologies that actively affect human motor actions, and may restore, enhance, or provide new human perceptual, cognitive, or physical abilities. The active assist is informed by wearable sensors and needs to anticipate and co-adapt with the operator. Through her research, Stirling enables wearable sensors and exosystems to be translated to operational environments.

Peter Szolovits: Professor Szolovits continues to do research on natural language processing of clinical notes and on building predictive models that estimate the risks of various morbid events and the likelihood of success of different therapeutic interventions. He serves as overall principal investigator of the medical collaboration between Royal Philips N.V and MIT, and continues to collaborate with colleagues at Philips, IBM, MGH, BIDMC, Tufts Medical Center, Harvard Medical School, University of Massachusetts, Lowell, and George Mason University, on a variety of projects. His group's research turns more and more toward incorporating many different modalities of clinical data, including imaging and genetic data in addition to laboratory test results, medications, diagnoses, procedures, and clinical notes. This encourages work on representation learning—that is, learning which combined representations best capture the linked information across modalities. The group continues to grow, reflecting tremendous interest among students in artificial intelligence applications in health care.

Professors of the Practice

Joseph Frassica: Professor Frassica leads the Philips Research Americas Laboratories. His research interests cover a broad range of topics, from the use of high-resolution physiologic data and clinical information to create predictors of patient trajectories in critical care, developing new measurements for ultra-mobile ultrasound, to the application of whole genome sequencing to track the spread of multi-drug-resistant bacteria within geographies and health care environments.

Frassica's laboratory recently began work on a joint US Department of Defense grant in collaboration with Thomas Heldt to develop a prototype of a device to measure intracranial pressure non-invasively. This $3 million grant spans three years and will bring to life a concept initially developed by Professor Heldt. The combined expertise of the Heldt and the Philips Laboratories will move this novel idea closer to the bedside.

Bruce D. Walker: Bruce Walker is the founding director of the Ragon Institute of MGH, MIT, and Harvard. He is also a professor of the practice in the Institute for Medical Engineering and Science and a Howard Hughes Medical Institute Investigator.

The goal of the Walker Laboratory is to define the interplay of immunologic, virologic, and host genetic factors that determine control of human viral infections in order to guide 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 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 (so-called controllers), some for 35 years or more. Vaccines currently entering efficacy trials are unlikely to prevent infection completely, but would represent a successful functional cure if the vaccines maintain viremia below a certain level. The Walker Lab focuses on understanding this remarkable T-cell-mediated control of HIV, building on successive discoveries from studying human immunology in persons infected with HIV.

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. In the past year, Walker's scientific contributions were recognized when he received the Oxford University Litchfield Lectureship. Walker also again teamed with Howard Heller to teach the undergraduate course HST.434 Evolution of an Epidemic, in South Africa during the January intersession. The class, sponsored in part by IMES, consists of lectures and field trips to interact with affected communities and to visit traditional healers, hospitals, and clinical research sites.

Events

HST Faculty Poster Session

More than 100 people attended the 2018 HST Faculty Poster Session held on October 4, 2018, at Harvard Medical School. Thirty-nine faculty posters, representing 34 labs were on exhibit. Some posters represented broad research programs while others presented specific research projects; some included student co-authors. This annual event familiarizes faculty members with their colleagues' research and allows them to recruit students to their laboratories. It also assists students beginning the process of selecting laboratories and mentors for their research.

HST Forum

The 33rd HST Forum was held on April 10, 2019, at the Tosteson Medical Education Center at Harvard Medical School. This event highlights the depth and breadth of HST student research for applicants admitted to HST's MD and PhD programs as well as current students, faculty, staff, and other members of the Harvard and MIT communities.

This year, approximately 125 people attended the forum, including 36 students who presented posters on their current research. The poster session was followed by a keynote address given jointly by IMES Director Elazer Edelman and his advisee, HST and MEMP student Shriya Srinivasan. They treated the audience to a unique view of a dynamic mentor/mentee relationship.

The following students received the Martha Gray Prize for Excellence in Research in the categories named:

- David "DJ" Bozym (MD): cell and molecular biology
- Sebastian Palacios (GEMS): regenerative and rehabilitative biomedical engineering
- Vicente Parot (MEMP): imaging, acoustics and optics
- Katherine Redfield (MD): physiology and systems biology
- Roman Stolyarov (MEMP): biomedical devices
- Jeremiah Wala (MD/PhD): bioinformatics and integrative genomics

IMES Distinguished Speaker Series

This year, IMES held four invited lectures that included the following speakers and subjects:

- Josh Makower: "Biomedical Innovation: A Transformation from Phenomenon to Proven Process," September 13, 2018
- Calum MacRae: "Building Multiscale Systems to Integrate Biomedical Discovery and Translation," November 29, 2018
- Philippe Pibarot: "Aortic Valve Stenosis: Quantifying Disease and Therapeutic Impact of New Interventions," February 7, 2019
- Ellen Kuhl: "Machine Learning in Drug Development," April 17, 2019

Research Progress Talks

IMES hosted a series of events to increase awareness of different research within the Institute. Each month, postdoctoral associates and students from two laboratory groups presented their research to the IMES community, including faculty, researchers, students, and staff. These events encourage collaboration between labs at IMES and are great opportunities for postdocs to practice their talks before applying for jobs or presenting at conferences.

Elazer Edelman
Director