Dean, School of Science

The School of Science has been committed to excellence in education and cutting-edge scientific research since it was established in 1932, when MIT sought not only to add basic science to its curriculum, but to contribute new knowledge to scientific disciplines. The School made long-term investments in its faculty, recruiting young scientists, giving them the support they needed to build their research programs, and retaining them as they begin to achieve their goals. The return on these investments were not immediate: while faculty at Columbia University, the University of Chicago, Harvard University, and the University of California, Berkeley were winning Nobel Prizes in the 1930s, MIT faculty and staff members did not begin to win them until the 1950s. Now, however, each of the six departments within the School is ranked at the top of its field. Our faculty produces a constant stream of research that seeks to answer fundamental questions about nature, ranging in scope from the microscopic—where a neuroscientist might isolate the electrical activity of a single neuron—to the telescopic—where an astrophysicist might scan hundreds of thousands of stars to find Earth-like planets in their orbits. The significance of our faculty's work is well recognized: in the past two decades, our faculty has received 10 Nobel Prizes, one Abel Prize (the equivalent of a Nobel in mathematics), and innumerable other awards for research and service.

Today we find ourselves facing new challenges to sustaining our commitment to basic science. With declining funding on the horizon, there is a temptation to abandon more abstract questions about the nature of the world around us and to focus resources on endeavors with more tangible results. But however worthwhile these practical undertakings, we cannot lose sight of the value inherent in basic research. As educators and researchers, the School's faculty pursues the great beauty in the universal truths that have been and will be discovered. For example, students learn in freshman physics that two phenomena that look wildly different on their faces, electricity and magnetism, are in fact part of one force: a discovery that surprises with its elegance. Moreover—although we cannot predict when or how—the pursuit of universal truths has the power to revolutionize technology. For instance, Claude Shannon used universal and abstract ideas in developing the mathematics to describe information and its transmission. In the process, he built the foundation for much of information technology. By cultivating the minds and the resources necessary for basic science, we safeguard our ability to make transformative advances in science and technology in the future. This year, the School of Science has worked diligently to maintain its investment in the future through cultivating and supporting new academic and research programs, and through the accomplishments of the School's outstanding faculty and staff.

Initiatives and Programs

Renovation of Building 2

In summer 2013, construction began on the renovation of Building 2, which is part of the Institute's comprehensive plan to refurbish the historic Bosworth Buildings in anticipation of their 100th anniversary in 2016. Since it was built, Building 2 has not been altered in any significant way. Major renovations are needed not only to create a more attractive and useful home for MIT's mathematicians, but also to update the antiquated infrastructure of the building. This long-anticipated renovation will enliven the Math Department quarters by providing attractive conference, seminar, and casual community spaces for small-group interaction. Offices will be laid out thoughtfully for the way mathematicians work today. There will be suites of graduate student offices and instructor offices opening onto shared meeting areas so that discussions and office hours will not interfere with quiet concentration.

Intelligence Initiative

The Intelligence Initiative (I^2) reintegrates cognitive science, computer science, and artificial intelligence, which flourished together in the 1950s and 1960s at MIT under the auspices of such scholars as Claude Shannon, Norbert Weiner, Noam Chomsky, and Marvin Minsky. Research supported by I^2 is organized around issues of physical, molecular, and collective intelligence. I^2 is designed to target research and education in an integrated way, developing faculty, graduate students, and postdoctoral fellows who can carry out highly interdisciplinary and collaborative work. The initiative supports eleven I^2 seed projects, with participants from the Departments of Biological Engineering, Biology, Brain and Cognitive Sciences (BCS), Electrical Engineering and Computer Science, and Linguistics, and from the Laboratory for Information and Decision Systems, the Computer Science and Artificial Intelligence Laboratory, the Media Laboratory, and the Sloan School of Management.

This year, the Intelligence Initiative gave rise to the Center for Brains, Minds, and Machines, a multi-institutional collaboration headquartered at MIT. The center aims to revive MIT's early ambitions to engineer artificial intelligence by improving our understanding of how the brain gives rise to intelligence, as well as to engineer it. The center works with several academic and industrial partners to catalyze continuing progress in, and cross-fertilization between, computer science, mathematics and statistics, robotics, neuroscience, and cognitive science.

Simons Center for the Social Brain

In 2012, the Simons Center for the Social Brain was established with the mission of understanding the neural mechanisms that underly social cognition and behavior, and to translate this knowledge into an understanding of autism spectrum disorders. The center, led by Newton professor of neurosciences Mriganka Sur, is supported by a grant from the Simons Foundation Research Initiative and is a successor to MIT's Simons Initiative on Autism and the Brain.

Education

MIT is exceptional among major research institutions for its dedication to undergraduate education. Unlike most leading schools of science, MIT puts great emphasis on hiring and promoting young faculty members and using undergraduate teaching as an important criterion for promotion and tenure. It is not uncommon for Nobel Prize winners and others among our foremost researchers to teach freshman subjects. The School and its departments participate in and support a variety of programs designed to create more active, student-centered learning environments inside the classroom.

For instance, the Department of Physics participates in both the d'Arbeloff Interactive Mathematics Project and the Technology-Enabled Active Learning program, which integrates technology into coursework to help students engage with concepts. Likewise, the Undergraduate Research-Inspired Experimental Chemistry Alternatives curriculum integrates cutting-edge research with core chemistry concepts.

MITx

In order to support MIT's ambitious goal of establishing leadership in online education through involvement with edX and the MITx initiative, faculty members in the School of Science are partnering with Sanjay Sarma, Karen Wilcox, and Israel Ruiz on the Institute-Wide Task Force on the Future of MIT Education. The Departments of Biology and Physics have both successfully launched courses, 7.00x Introduction to Biology, 8.01x Classical Mechanics, and 8.02x Electricity and Magnetism. The Department of Earth, Atmospheric, and Planetary Sciences (EAPS) will launch 12.340x Global Warming Science under the leadership of Kerry Emmanuel. Several faculty members have begun to experiment with the platform or launch short courses.

Teaching Prizes for Graduate and Undergraduate Education

To reward individual faculty members for supporting the Institute's mission to foster strong teaching, the School of Science awards student-nominated professors with the School of Science Prizes in Undergraduate and Graduate Teaching. This year, the School recognized Jonathan Kelner, the Kokusai Denshin Denwa assistant professor of applied mathematics, and Nergis Mavalvala, the Curtis (1963) and Kathleen Marble professor of astrophysics. Kelner teaches 18.440 Probability and Random Variables; Mavalvala teaches 8.13 Experimental Physics.

Research

The School of Science faculty made significant advances in a broad range of research fields this year, ranging from quantum computing and the neurophysiology of Parkinson's disease to the irregular gravitational field of the moon. What follows are a few notable examples.

Raymond Ashoori, professor of physics, and Pablo Jarillo-Herrero, Mitsui career development associate professor of physics, transformed graphene so that it had a "band gap," a property necessary to make transistors and other electrical devices. Ashoori and Jarillo-Herrero placed a sheet of graphene, which is composed of a one-atom-thick hexagonal lattice of carbon, on top of a sheet of another hexagonal lattice, this one made of boron nitride. When the lattices are perfectly aligned, the resulting material becomes a semiconductor, retaining both the conductivity of graphene and the insulating properties of boron nitride. Moreover, when the material is exposed to a magnetic field, it produces a Hofstadter butterfly energy spectrum, a phenomenon thought to be impossible in the real world until the publication of these results and the work of two other groups in the same week.

Moungi Bawendi, the Lester Wolfe professor in chemistry, developed a method of measuring the spectral peak of quantum dots that will help researchers improve the purity of the dots' color emissions. Quantum dots are extremely small particles of matter that can emit light with very bright, pure color, and have potential applications for television and computer screens and biological markers. Until now, researchers had no way of knowing whether the variability in the colors of any batch of quantum dots was an effect of individual particles or of the whole ensemble. Bawendi's new method, called photon-correlation Fourier spectroscopy in solution, illuminates a sample with a laser beam, detecting emitted light at very short timescales. The process gives the average spectral width of the billions of particles of an ensemble, indicating whether individual particles are producing pure colors or not. Bawendi's group has used the process to confirm that cadmium selenide, a material already used widely for quantum dots, does indeed emit pure colors, and the group has identified new materials as potential alternatives, such as indium phosphide.

A team of researchers that included Samuel Bowring, the Robert R. Shrock professor of geology, discovered strong evidence confirming the link between the End-Triassic mass extinction and volcanic eruptions, both of which occurred approximately 200 million years ago. Many scientists theorize that volcanic eruptions in the Central Atlantic Magmatic Province (CAMP) released enough carbon dioxide, sulfur, and methane to cause intense global warming and acidification of the oceans, which in turn led to the extinction of thousands of species of plants and animals. However, scientists were not certain that the CAMP eruptions produced the gases in a short enough period of time to make a significant impact on the environment and did not have a precise enough date for the eruptions to confirm that the eruptions and the mass extinction occurred at the same time. Bowring and his colleagues combined painstaking astrochronological and geochronological methods of dating sedimentary and igneous rock from Morocco and the east coast of the US (once joined together in Pangaea). They precisely dated the CAMP eruptions at 201 million years ago, pinpointing three bursts of activity over 40,000 years that coincided with the mass extinction.

Laurie Boyer, the Irwin and Helen Sizer career development associate professor of biology, published two papers relating to the embryonic development of heart cells. In the first study, her group treated embryonic stem cells with proteins and growth factors known to drive heart development and then tracked the cells' histone modification patterns. At each stage of development the cells were analyzed. The researchers identified several groups of genes with related functions, transcription factors previously linked to heart defects collected at regulatory regions, and active regulatory regions far away from the genes under regulation. The second study focused on one long, non-coding RNA (lncRNA) sequence associated with heart development called "Braveheart." Braveheart was found to stimulate the transformation of embryonic cells into heart cells. The lncRNA works by interacting with a complex, MesPI, which usually sits atop DNA, blocking its transcription and thereby initiating a cascade of hundreds of genes needed for heart development. The laboratory believes that this discovery could pave the way for improved treatment of heart disease and congenital heart defects, and plans to continue its study of Braveheart by analyzing the mechanism of its action.

Institute and Brain and Cognitive Sciences professor Ann Graybiel discovered new facets of the Parkinson's disease pathway that may help explain why the current standard treatment of L-dopamine remains effective for only five to 10 years. In the experiment, researchers disabled dopamine-releasing cells in rats to mimic Parkinson's. Researchers then monitored the activity of two kinds of neurons while the rats learned to run a maze: projection neurons, which send messages from the striatum to the neocortex to initiate or halt movement, and fast-spiking interneurons, which enable local communication within the striatum. Researchers found that the dopamine-depleted projection neurons fired in the same pattern as normal neurons, although more intensely, and that fast-spiking interneurons were totally disabled by the lack of dopamine. When researchers treated both types of neurons with L-dopamine, normal activity of the projection neuron returned, but normal activity did not return for fast-spiking neurons. This is the first study to show that the effects of dopamine loss depend on the type of neuron. The Graybiel laboratory is now working on measuring dopamine levels in other parts of the brain as rats learn new behaviors and on finding ways to restore function to interneurons that no longer respond to L-dopamine.

Mathematics professor Jonathan Kelner led a team of researchers that proposed a significantly faster and simpler method of solving graph Laplaceans, a type of calculation with a number of applications in computer science, including scheduling, image processing, online product recommendation, network analysis, and scientific computing. A graph Laplacean is a matrix of numbers describing a mathematical diagram wherein nodes are connected by edges that represent relationships and can be weighted. For instance, the nodes can represent tasks in a complex operation and the edges connecting them can be weighted by cost and time. A Laplacean describes the weight of all the edges in a graph, and in the past has usually been solved by creating a series of increasingly simple approximations of the graph. However, the rules for constructing the series are complicated and proving that the simplest graph approximates the most complex requires sophisticated mathematics. Kelner's new approach involves using already well-established algorithms for finding a spanning tree for the graph, wherein edges are traced such that every node is touched without creating any closed loops. As missing edges are added back one at a time, calculations of the Laplacean are recalibrated, eventually converging on the solution. Kelner believes that the approach should be faster and easier to implement in software than its predecessors and that it can be used to solve problems in other contexts.

Arthur Amos Noyes professor Stephen Lippard discovered a new compound, phenanthriplatin, which promises to be more effective in destroying cancer cells and have fewer side effects than existing platinum-containing anti-cancer compounds, such as the widely used cisplatin. Phenanthriplatin was tested on 60 different cancer cell types and was four to 40 times more effective than cisplatin in killing cells. In platinum-based compounds, the platinum is usually bound to ammonia molecules and chloride ions. When the compound enters the cell, water replaces the chloride ions, giving the compound a positive charge. The compound can then bind to negatively charged DNA, preventing transcription. Lippard's phenanthriplatin contains large carbon rings that not only block transcription more effectively than other compounds, but also allow the compound to target cancer-specific channels in the cell membrane for entry. The rings also protect the platinum at the center from sulfur-containing compounds in the cell that can render other compounds inactive. The Lippard laboratory is currently working on testing phenanthriplatin on animals to determine how the compound is distributed through the body and how well it kills tumors.

Peter Shor, the Morss professor of applied mathematics, took a theoretical approach to constructing spin chains that may help advance the development of quantum computing. Quantum computing takes advantage of subatomic particles' alignment with a magnetic field, or "spin," and requires those spins to be "entangled," so that measuring the spin of one particle will indicate the spin of another. The computing capacity of this system depends on the properties of a spin chain, including its complexity (the number of possible spin states for any particle), the degree of entanglement among its particles, and its length. Theoreticians have argued that a high degree of entanglement is possible only with a complex spin chain: after a certain point, adding more particles to a simple chain with only a few available spin states does not increase entanglement. Shor refuted this theory by showing that it is possible to construct a spin chain with only three available states that yet has entanglement without bound, where any such chain with a net energy of zero can be converted to any other through a short sequence of energy-preserving substitutions.

Samuel Ting, the Thomas D. Cabot professor of physics, announced the first results for the Alpha Magnetic Spectrometer (AMS) in its search for dark matter, reporting an excess of positrons in the cosmic ray flux that shows no significant variations over time and that appears to emanate from many directions. Dark matter is one of the most important mysteries in physics: although dark matter makes up a fourth of the universe's mass–energy balance, it can be observed only indirectly through its interactions with visible matter. The AMS experiment was conceived by Professor Ting about 18 years ago and involves 650 researchers from 50 universities and agencies in 16 countries. Since the AMS was installed on the International Space Station in 2011, it has recorded around 30 billion events, 6.8 billion of which were positrons—the largest collection of antimatter particles recorded in space. The AMS results are consistent with supersymmetry theories that propose that positrons originate in the annihilation of dark-matter collisions in space; however, they do not preclude the possibility that positrons come from pulsars evenly distributed around the galactic plane. The next steps for the project are to refine the instrument's precision and to explore the behavior of particles at higher energies, which are predicted to decline abruptly in frequency if they derive from dark matter.

NASA's Gravity Recovery and Interior Laboratory (GRAIL) project, led by E. A. Griswold professor of geophysics Maria Zuber, solved the long-standing mystery of why the moon has a "bumpy" gravitational field. Since the first satellites were sent to scout the moon, scientists have observed that certain areas of the moon's gravitational field, dubbed "mascons," pull objects more strongly toward the lunar surface than others. Researchers mapped the mascons with GRAIL's twin probes, Ebb and Flow, revealing a bull's eye pattern of alternating rings of negative and positive gravity around a strong center of positive gravity. Simulations showed that the bull's eye pattern was produced only when an asteroid struck the moon where the crust was relatively thin, producing a shockwave that reverberated through the crust, followed by a counterwave that drew dense material in the mantle toward the surface of the center of the crater. Then, as the surface cooled and relaxed over tens of millions of years, the dense material settled in bands around the center of the crater. Not only did the results explain a 45-year-old mystery, but they may give clues to the formation of the Earth, which, like the moon, was impacted heavily during the period known as the Late Heavy Bombardment—a period that coincides with the emergence of the first single-celled organisms.

Events

Dean's Colloquium

The Dean's Colloquium is a series of lectures designed to recognize scientists who began careers in science but have outstanding accomplishments outside scientific research. This year's lecture featured Susan Solomon, the Ellen Swallow Richards professor of atmospheric chemistry and climate science in EAPS. Her talk, "The World's Chemistry in Our Hands: Global Environmental Challenges, Past and Future," explained how combinations of science, public policy, and citizen engagement can lead to environmental solutions and inform responses to key challenges of the 21st century, especially climate change.

School of Science Breakfast Series

This year, the School of Science continued its successful Breakfast Series, featuring faculty members and research from around the School. One such talk in December, "Is MIT the New 'Bell Labs' of Disease Research?" showcased the School's talented faculty and their numerous collaborations with nearby hospitals that make MIT so instrumental to research in areas such as Alzheimer's disease, autism, cancer, and psychiatric disorders. In another talk, Taylor Perron, the Cecil and Ida Green assistant professor of geology, showed his audience how to see familiar features of the landscape such as river networks and sand ripples in a new way; despite how common they are, and despite their frequently organized, repeating patterns, their origins are a mystery that researchers like Perron are only now just beginning to explain with the help of combinations of mathematical models, high-resolution topography, and field measurements.

Awards and Honors

Faculty Awards and Honors

Every year, academic and professional organizations honor numerous School of Science faculty members for their innovative research as well as for their service to the community. This past year was no exception, and the individual reports from the School's departments, laboratories, and centers will document these awards more completely. However, several notable awards deserve special mention here.

Stephen Buchwald, the Camille Dreyfus professor of chemistry, received the Arthur C. Cope Award from the American Chemical Society.

Sallie "Penny" Chisholm, the Lee and Geraldine Martin professor of environmental studies and professor of biology, was awarded a 2013 National Medal of Science.

Alan Guth, the Victor F. Weisskopf professor of physics, was among nine physicists worldwide selected as inaugural winners of the Fundamental Physics Prize; each winner received $3 million.

Rudolph Jaenisch, professor of biology, received the Benjamin Franklin Medal in Life Science from the Franklin Institute.

Pablo Jarillo-Herrero; Pawan Sinha, professor of Brain and Cognitive Sciences; and Jesse Thaler, assistant professor of physics, were named recipients of the Presidential Early Career Awards for Scientists and Engineers.

Stephen J. Lippard was named recipient of the 2014 Priestley Medal, the highest honor conferred by the American Chemical Society. He was also the recipient of MIT's 2013 James R. Killian Jr. Faculty Achievement Award.

Peter Reddien, associate professor and associate head of the Department of Biology, and Aviv Regev, associate professor of biology, were named Howard Hughes Medical Institute Investigators.

Timothy Swager, the John D. MacArthur professor of chemistry, received the Award for Creative Invention from the American Chemical Society.

The following professors were elected as members to the American Academy of Arts and Sciences:

- Samuel A. Bowring, the Robert R. Shrock professor of geology
- Martha Constantine-Paton, professor of brain and cognitive sciences and McGovern Institute Investigator
- Robert Jaffe, the Otto (1938) and Jane Morningstar professor of physics
- Ernest Moniz, the Cecil and Ida Green professor of physics and engineering systems and the director of the MIT Energy Initiative and MIT's Laboratory for Energy and the Environment

The following professors were elected as fellows of the American Association for the Advancement of Science:

- Jianzhu Chen, the Ivan R. Cottrell professor of immunology
- Sallie Chisholm, the Lee and Geraldine Martin professor of environmental studies
- Samuel Ting, the Thomas Dudley Cabot professor of physics

- The following professors were elected as members of the National Academy of Sciences:
- Robert Field, the Haslam and Dewey professor of chemistry
- Victor Kac, professor of mathematics
- David Vogan, professor of mathematics
- Graham Walker, professor of biology

School of Science Rewards and Recognition

The School of Science Rewards and Recognition Program continues to acknowledge the dedication and hard work of the people who fill our departments, laboratories, and centers and whose efforts are the source of the School's prestige. The Dean's Educational and Student Advising Award Program rewards employees for their dedication to the success of their educational programs and of the students they advise. The School continues its Spot Awards, which rewards employees "on the spot" for going beyond the requirements of their normal duties. The Infinite Mile and Infinite K Awards recognize School of Science employees for their dedication to the School and their willingness to go far beyond the extra mile to accomplish everything that needs to be done.

Personnel

Appointments and Promotions

Mohammed Movassaghi, Iain Stewart, and Martin Zwierlein were promoted to full professor in the Department of Physics.

Michael Hemann (Biology), John McGreevy (Physics), Robert Simcoe (Physics), and Katrin Wehrheim (Mathematics) were granted tenure. Mick Follows was appointed as associate professor with tenure in EAPS.

The following were appointed as associate professors without tenure: Allan Adams (Physics), Nuh Gedik (Physics), Wendy Gilbert (Biology), Oliver Jagoutz (EAPS), Pablo Jarillo-Herrero (Physics), and Lie Wang (Mathematics).

The following were appointed as assistant professors: Gloria Choi (BCS), Jörn Dunkel (Mathematics), Matthew Evans (Physics), Aram Harrow (Mathematics), Mehrdad Jazayeri (BCS), Yen-Jie Lee (Physics), Joshua McDermott (BCS), Ankur Moitra (Mathematics), German Prieto (EAPS), Hilke Schlichting (EAPS), Tracy Slatyer (Physics), Charles Smart (Mathematics), Yogesh Surendranath (Chemistry), and Adam Willard (Chemistry).

Faculty Lunch Programs

Tenure-track faculty lunch meetings are intended to help junior faculty meet their peers in different departments and to provide a forum for discussion of important issues. This year, several faculty members presented their research, while other meetings covered such topics as faculty benefits and creating engaging and memorable lectures. A similar lunch series exists for mid-career faculty members in the school. These lunches allow mid-career faculty members to build their network of colleagues and collaborators and to participate in the administration of the School. The format for these lunches usually includes a research presentation followed by questions and answers from the audience.

School of Science Learn@Lunch Series

To provide administrative staff the support they need to do their jobs as effectively as possible, the School of Science holds a monthly lunch series for staff members on a variety of subjects. This year, the program focused on topics for supervisors and included talks on performance reviews, conducting interviews, setting goals, mentoring, and employee engagement.

Marc A. Kastner
Dean
Donner Professor of Physics