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. To make such a commitment, 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 returns on our investments were not immediate: for instance, while faculty members at Columbia, Chicago, Harvard, and Berkeley were winning Nobel Prizes in the 1930s, the first MIT faculty and staff did not 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 last two decades, our faculty has been distinguished by 10 Nobel Prizes, one Abel Prize (the equivalent of a Nobel in mathematics), and innumerable other awards for research and service.

However, we now find ourselves facing new challenges to sustaining our commitment to basic science. With declining funding on the horizon, there is temptation to abandon more "abstract" questions about the nature of the world around us and to focus our resources on endeavors with more tangible results, such as finding secure sources of energy, curing disease, safeguarding our environment, or building new businesses that will keep the economy strong. But, however worthwhile these practical undertakings, we cannot lose sight of the value inherent in basic research. As educators and researchers, our faculty members pursue the great beauty in the universal truths that have been and will be discovered. For example, we 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 us with its elegance. Moreover, though we cannot predict when or how, our 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, and in the process built the foundation for much of information technology. By cultivating the minds and the resources necessary for basic science at MIT now, 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 our investment in the future, through cultivating new academic and research programs, supporting the research programs of our new and existing faculty members, and through the accomplishments of our outstanding faculty and staff.

Initiatives and Programs

Intelligence Initiative

In cooperation with all five Schools and spearheaded by Professors Joshua Tenenbaum (Brain and Cognitive Science, [BCS]) and Tomaso Poggio (BCS and Computer Science and Artificial Intelligence Laboratory), the School of Science launched the Intelligence Initiative (I^2) in 2010. I^2 reintegrates cognitive science, computer science, and artificial intelligence, which flourished together in the 1950s and '60s at MIT under the auspices of such scholars as Claude Shannon, Norbert Weiner, Noam Chomsky, and Marvin Minsky. The ongoing research supported by I^2 is organized around issues of physical, molecular, and collective intelligence. The initiative supports eleven I^2 seed projects, spanning Computer Science, Linguistics, Mechanical Engineering, the Media Laboratory, and the Sloan School of Management. 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.

Lorenz Center

In September 2010, the School of Science launched the Lorenz Center, a new climate think tank devoted to fundamental inquiry. By emphasizing high-risk, curiosity-driven research, the Lorenz Center aims to attract an interdisciplinary group of top scientists who will focus on the enormous scientific challenge of understanding the physics, biology, and chemistry of the climate system. Earth, Atmospheric and Planetary Science professors Kerry Emanuel and Daniel Rothman are leading this effort, which is named after their late colleague Edward N. Lorenz, founder of modern chaos theory and an early contributor to climate science. In October, the Lorenz Center hosted its first annual John Carlson Lecture with Paul Hoffman, the Sturgis Hooper professor of geology, emeritus, at Harvard University. Conceived as a public lecture on climate science for the widest of audiences, it proved so popular that Hoffman's talk was standing room only.

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 best researchers to teach freshman subjects. Committed to providing MIT undergraduates with a strong science base for studies in their major, 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. The Department of Physics participates in both the d'Arbeloff Interactive Mathematics Project and the Technology-Enabled Active Learning program, which integrate technology into coursework to help students engage with concepts. The Undergraduate Research-Inspired Experimental Chemistry Alternatives curriculum integrates cutting-edge research with core chemistry concepts.

In order 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 two faculty members for graduate teaching, Mathematics professor Mark Behrens and Biology professor Frank Solomon.

Research

The School of Science faculty made significant advances in a broad range of research fields this year, ranging from the development of mathematical models that predict the behavior of useful materials to the elucidation of the molecular pathways of Alzheimer's to the discovery of new planets. More complete accounts of research accomplishments will be given by each department, but a few are featured below.

Mathematics professor Martin Bazant explained the unique behavior of lithium iron phosphate, a rechargeable battery material that is safe, durable, and able to deliver large bursts of energy as long as it is in nanoparticle form. Contrary to prevailing theories that particles absorbed lithium from the outside in, Bazant showed that at low current bands of lithium-poor and lithium-rich material form, and at high current particles absorb lithium all at once. While low current bands lead to stress and cracking, at high current the material remains largely intact. Bazant's findings may significantly advance the development of rechargeable batteries for high-power applications, such as electric cars.

In collaboration with researchers from Georgia Institute of Technology, BCS professor Ed Boyden developed an automated method for recording the electrical activity of single neurons in living brain tissue. The team developed a robotic arm that replicates whole-cell patch clamping, a neuron-by-neuron technique so difficult that very few labs practice it. The new apparatus can also be used to determine the shape of a cell and, soon, to extract DNA. The team will scale up the number of electrodes in hopes of understanding how the different parts of the brain are connected, and is working with other labs to catalogue the thousands of types of neurons by shape, electrical activity, and genetic profile.

Physics professor Mildred Dresselhaus discovered a new material consisting of a thin layer of bismuth-antimony that possesses properties similar to graphene. Like graphene, the material possesses two-dimensional Dirac cones that allow electrons to move as if they were relativistic particles without mass, suggesting that the material could lead to the development of computer chips in which electrons flow hundreds of times faster than in conventional silicon chips. Research further showed that the new material is capable of displaying a variety of characteristics, depending on factors such as ambient temperature and pressure, thickness, and orientation of the growth of the material. Because these properties were determined by theoretical modeling, further testing is planned.

A team of researchers that included Mathematics professor Alan Edelman and Chemistry professor Troy Van Voorhis developed an effective mathematical simulation of the electronic behavior of non-crystalline or "disordered" materials such as the amorphous silicon used to make solar cells. Their method employs free probability applied to random matrices, a concept never before applied to real-world conditions. Until now, using matrices to calculate properties has been problematic for disordered materials, since the values for the numbers in the matrix are too imprecise to produce useful predictions. The new approach solves the problem by using probability distribution in lieu of precise values and is capable of producing results that replicate the exact solution so closely that it is impossible to discern the difference with the naked eye. The new method is the first step toward more cost-effective computational modeling of new kinds of solar materials and devices.

Daniel K. Ludwig professor for cancer research Richard Hynes demonstrated that platelets play a significant role in metastasis by providing a growth factor, TGF-beta, which in turn triggers epithelial-mesenchymal transition, wherein cancerous cells lose their ability to adhere to one another and migrate from their original location. Hynes's findings refute previous theories that platelets facilitated metastasis either through their normal role in promoting cell adhesion or through forming a physical barrier around cancerous cells that protected them from natural killer cell-mediated lysis and shear stress. The improved understanding of the role of platelets will have important implications in the development of drugs that impede metastasis.

In collaboration with Florida State University professor Kevin Speer, the Cecil and Ida Green professor of oceanography, John Marshall, has revised the "conveyor belt" model of the Earth's ocean current. While in the conveyor belt model, carbon and heat were thought to be sequestered by warm southern currents plunging deep into the North Atlantic basin and released by upwelling currents in the North Pacific. Marshall and Speer showed that deep currents emerge instead in the Southern Ocean surrounding Antarctica. Their findings have an important bearing on how we understand climate warming. Whereas in a cooling world winds move toward the equator where continents act as windbreaks, in a warming world winds move toward the poles where they are not impeded, agitating the oceans and dredging up buried warm water and carbon at a faster rate. The phenomenon is intensified by trends driven by human activity, such as ozone depletion and greenhouse gas emissions, which shift winds to the south and release carbon at a yet faster rate. Marshall is working with the Woods Hole Oceanographic Institution to measure how fast waters resurface in the Southern Ocean, as well as water temperature, salinity, and oxygen content.

Professor of physics and health sciences technology Leonid Mirny showed that the DNA deletions and duplications characteristic of cancerous cells depend on the three-dimensional architecture of the chromatin. This new finding builds on 2009 work showing that DNA forms a "fractal globule" in which strands are tightly packed yet do not cross, rather than forming a tangled "equilibrium globule" as previously theorized. In the new study, Mirny found that any two points on DNA strand frequently in proximity are more likely to become the end of a loop that is duplicated or deleted. The findings could help cancer researchers identify hotspots for genes that cause or suppress cancer.

Frederick G. Keyes professor of chemistry Richard Schrock built on his 2005 Nobel Prizewinning work on olefin metathesis by developing a catalyst that almost exclusively produces the more desirable cis-configured molecules rather than the more frequently synthesized trans-configured molecules. Configuration is important in pharmaceutical synthesis because, in nature, most compounds are cis-configured and thus are thought to interact better with biological structures. Schrock's catalyst has a large ligand attached to the tungsten that blocks carbon atoms from attaching in the trans-configuration. The process has already been used to synthesize two naturally occurring anti-cancer compounds, epothilone and nakadomarin.

In concert with an international team of scientists, Class of 1941 professor of physics and planetary science Sara Seager used the National Aeronautics and Space Administration's Kepler space telescope to identify two Earth-sized exoplanets orbiting Kepler 20, a system 950 light years away. The planets are the smallest yet to be detected, and were found to be extremely hot and have short years of six and 20 days. In another study, Seager also determined the temperature of Cancri 55e, a super-Earth at the relatively close distance of 40 light years, by using the Spitzer space telescope to observe the planet as it was occulted by its star passing behind it and measuring the fluctuations in infrared light. Seager found that Cancri 55e is approximately 3700° F and theorizes that the planet lacks reflective surfaces and thus absorbs more heat from its parent star than other planets that are similarly situated. This is the first time this method has been applied to a planet so small and it promises to help scientists characterize other exoplanets of even smaller size.

Picower professor of neuroscience Li-Huei Tsai showed that the inhibition of an enzyme called HDAC2 reverses Alzheimer's-like symptoms in mice and may have a similar effect in humans. HDAC2, like other histone deacetylases, causes DNA to wind more tightly on histone "spools," thus inhibiting gene expression. Tsai found that in mice with Alzheimer's-like symptoms, HDAC2 was overexpressed in the hippocampus, a region of the brain devoted to memory formation. Moreover, HDAC2 was usually bound to a cluster of genes also involved in new memory formation. Blocking transcription of HDAC2 increased expression of the gene cluster, restoring the mice's normal cognitive function. Postmortems of Alzheimer's patients' brains confirmed that, as in mice, HDAC2 was overexpressed in the hippocampus, indicating that HDAC2 inhibitors are a prime target for pharmaceutical development. The study also demonstrated why drugs that clear characteristic beta-amyloid clumps from the brain are not very effective: Although beta-amyloid stimulates the production of HDAC2, the removal of beta-amyloid does not affect the configuration of DNA, and the inhibition of genes related to memory formation persists.

David H. Koch professor in science and professor of biological engineering Michael Yaffe demonstrated that staggering the delivery of two drugs already approved for cancer treatment, erlotinib and doxorubicin, significantly increases their effectiveness on a particularly aggressive form of breast cancer. Yaffe's study focused on triple-negative breast cancer cells, so-called because this type of cell lacks overactive estrogen, progesterone, and HER2 receptors. Triple-negative cells account for 16% of all breast cancer cases and while the combination therapy usually used to treat it is effective at first,

a significant portion of patients develop recurrent cancer. By following a dose of erlotinib with doxorubicin four to 48 hours later, tumors in mice were not only destroyed, but did not recur. Yaffe is working with researchers at Dana-Farber Cancer Institute to begin clinical trials of the staggered drug therapy on triple-negative breast cancer cells, and expects that this approach will be widely applicable to other forms of cancer.

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 of scientific research. In October, Charles Zhang, PhD '94, gave a talk titled "From Experimental Physics to Internet Entrepreneurship: One Scientist's Journey," describing his evolution from humble beginnings in rural China to MIT physics graduate student to the founder, chairman, and CEO of Sohu.com (a leading Internet service provider in China). In December, James Simons, PhD '58, described his path from mathematician to founder and CEO of a successful hedge fund and, now, philanthropist in his talk "Mathematics, Common Sense, and Good Luck: My Life and Careers."

School of Science Breakfast Series

The School of Science continued its successful Breakfast Series. The series presents talks from around the School. The February talk featured mathematics professor Gilbert Strang, who gave a lecture on the connections between the probability of a random triangle being acute and the mathematical equation for processing the signal for high-definition TV. Earlier, in October, BCS professor Mriganka Sur gave a talk on his goal of uncovering the rules of the network wiring and the dynamics that underlie the plasticity of the adult brain.

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 their service to the community. This past year was no exception, and the individual reports from the School's departments, labs, and centers will document these awards more completely. However, several notable awards deserve additional mention here.

Professor of physics and engineering, emerita, Mildred Dresselhaus was awarded the Enrico Fermi Award, one of the oldest and most prestigious science and technology honors given by the US government, for her "leadership in condensed matter physics, in energy and scientific policy, in service to the scientific community, and in mentoring women in the sciences."

Two School of Science professors were honored with Kavli Prizes: Mildred Dresselhaus was given the Nanoscience Award "for her pioneering contributions to the study of phonons, electron-phonon interactions, and thermal transport in nanostructures" and Ann Graybiel, Institute Professor, was awarded the Neuroscience Prize "for elucidating basic neuronal mechanisms underlying perception and decision"

Physics professor Scott Hughes was awarded a Guggenheim Fellowship.

Professor of biology Rudolf Jaenisch was awarded the Benjamin Franklin Medal by the Franklin Institute "for discovering heritable controls of gene expression that are independent of the DNA sequence information."

Eric Lander, professor of biology, shared the one-million-dollar Dan David "Future" Prize with David Botstein and J. Craig Venter, awarded for their significant contributions to genome research and pioneering discoveries in genomics.

BCS professor Edward Boyden was named the inaugural recipient of the A. F. Harvey Engineering Research Prize by the UK's Institution of Engineering and Technology. The £300,000 prize was given in recognition of Boyden's pioneering research contributions to the field of optogenetics, in which neurons are genetically modified to respond to light. Boyden's development of optogenetics also won him the Perl/UNC Neuroscience Prize, which Boyden shares with BCS professor Feng Zhang.

Associate professor of cognitive neuroscience Rebecca Saxe was named a 2012 Young Global Leader by the World Economic Forum. The Swiss forum recognizes up to 200 out of thousands of exceptional young leaders under the age of 40 for their "professional accomplishments, commitment to society, and potential to contribute to shaping the future of the world."

Sara Seager, Class of 1941 professor of planetary science and physics, shared the Raymond and Beverly Sackler Prize with David Charbonneau of Harvard, awarded in recognition of Seager's "brilliant theoretical studies, including analysis of the atmospheres and internal compositions of extra-solar planets."

The American Chemical Society honored four Department of Chemistry professors with awards:

- Robert Field, ACS E. Bright Wilson Award in Spectroscopy
- Timothy Jamison, ACS Arthur C. Scope Scholar Award
- Robert Langer, ACS Priestley Medal
- Keith Nelson, ACS Ahmed Zewail Award in Ultrafast Science and Technology

Several professors were elected to prestigious academic and scientific societies this past year:

- Angela Belcher (Biology), Bonnie Berger (Mathematics), Emery Brown (BCS), Robert Griffin (Chemistry), Tyler Jacks (Biology), Bjorn Poonen (Mathematics), and Matthew Wilson (BCS): Fellows, American Academy of Arts and Sciences
- Sara Seager (EAPS/Physics) and Matthew Wilson (BCS): Fellows, American Association for the Advancement of Science
- Robert Langer (Biology), Stephen Lippard (Chemistry), and Steven Tannenbaum (Chemistry): Fellows, American Chemical Society
- Mriganka Sur (BCS) and Li-Huei Tsai (BCS): Members, Institute of Medicine
- Richard Young (Biology): Member, National Academy of Sciences

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, labs, and centers and whose efforts are the source of our 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

Professor of biology Chris Kaiser was named provost. Whitehead professor of biology Tania Baker succeeded him in his former role as department head of Biology.

Professor James DiCarlo was named department head of Brain and Cognitive Sciences.

Robert van der Hilst, the Schlumberger professor of earth and planetary science, was appointed head of the Department of Earth, Atmospheric and Planetary Sciences.

James DiCarlo (BCS), Ju-Lee Kim (Mathematics), Young Lee (Physics), Mohammad Movassaghi (Chemistry), Elly Nedivi (BCS), David Sabatini (Biology), and Troy Van Voorhis (Chemistry) were promoted to full professor.

Joseph Formaggio (Physics), Dennis Kim (Biology), Michael Laub (Biology), Peter Reddien (Biology), Laura Schulz (BCS), Joshua Winn (Physics), and Martin Zweirlein (Physics) all received tenure.

Tanja Bosak (EAPS), Laurie Boyer (Biology), Iain Cheeseman (Biology), Enectali Figueroa-Feliciano (Physics), Jonathan Kelner (Mathematics), Abhinav Kumar (Mathematics), Paul O'Gorman (EAPS), and Jeroen Saeij (Biology) were promoted to associate professor.

Daniel Cziczo (Chemistry), Jeremy England (Physics), Anna Frebel (Physics), Liang Fu (Physics), Jeremiah Johnson (Chemistry), David McGee (EAPS), Bradley Pentelute (Chemistry), Sug Woo Shin (Mathematics), Jared Speck (Mathematics), Goncalo Trigo Neri Tabuada (Mathematics), Kay Tye (BCS), Nevin Weinberg (Physics), and Paolo Zuccon (Physics) were appointed assistant professors.

Tenure-Track Faculty Lunch Program

These 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 mentoring and faculty benefits.

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. Topics for this year included how to lead interviews, performance reviews, and setting SMART goals.

Marc A. Kastner
Dean
Donner Professor of Physics