
Section 3

Campus Research

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Research Support

MIT has historically viewed teaching and research as inseparable parts of its academic mission. Therefore, the Institute recognizes its obligation to encourage faculty to pursue research activities that hold the greatest promise for intellectual advancement. MIT maintains one of the most vigorous programs of research of any university and conducts basic and applied research principally at two Massachusetts locations, the MIT campus in Cambridge and MIT Lincoln Laboratory, a federally funded research and development center (FFRDC) in Lexington.

MIT pioneered the federal/university research relationship, starting in World War II. Initially called upon by the federal government to serve the national war effort, that relationship has continued into the present day, helping MIT fulfill its original mission of serving the nation and the world.

Research Expenditures (MIT FY2012)

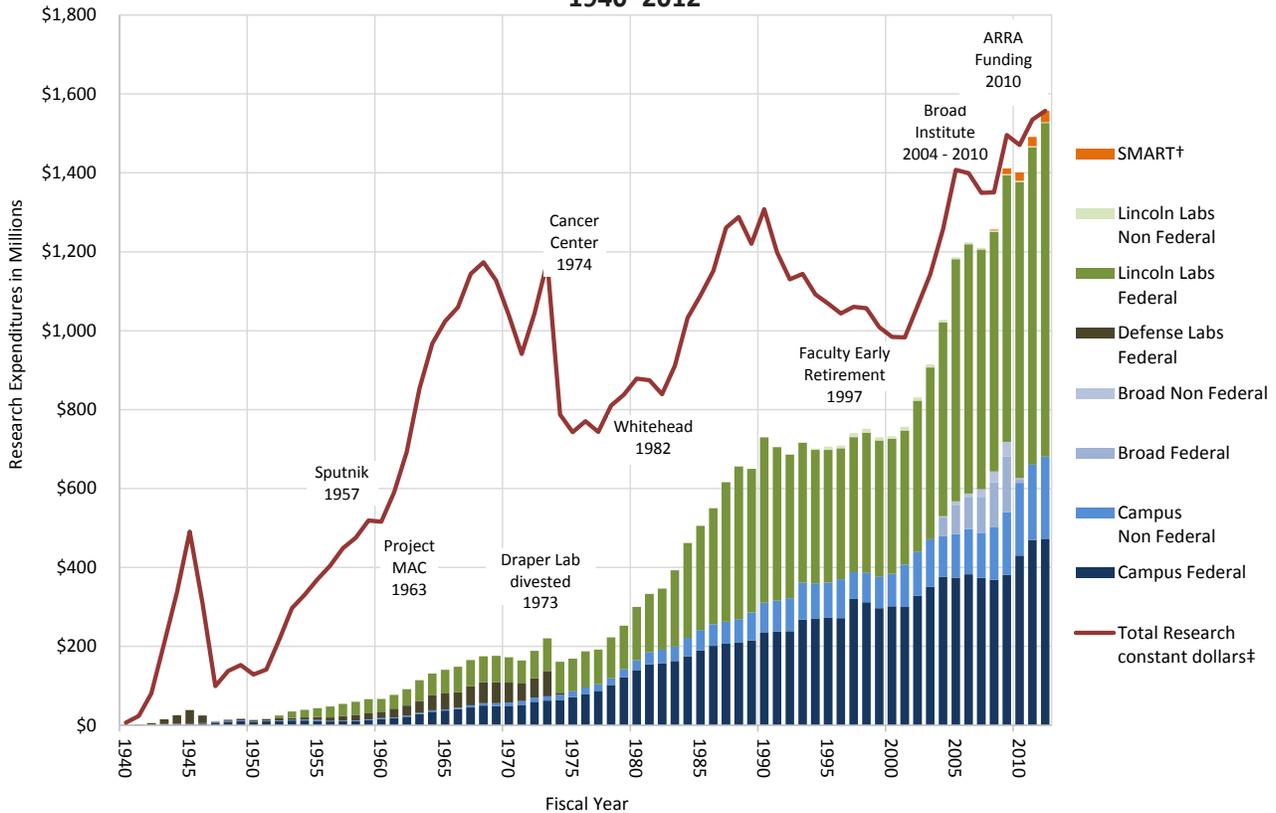
Cambridge campus	\$681 million
Lincoln Laboratory*	\$847 million
SMART*	\$29 million
Total	\$1.56 billion

*Totals do not include research performed by campus laboratories for Lincoln Laboratory and Singapore-MIT Alliance for Research and Technology (SMART).

All federal research on campus is awarded competitively based on the scientific and technical merit of the proposals. In FY2012, there were 2,540 active awards and 460 members of research consortiums.

Research activities range from individual projects to large-scale, collaborative, and sometimes international endeavors. Peer-reviewed research accomplishments form a basis for reviewing the qualifications of prospective faculty appointees and for evaluations related to promotion and tenure decisions.

**MIT Research Expenditures
1940–2012**



†SMART: Singapore-MIT Alliance for Research and Technology

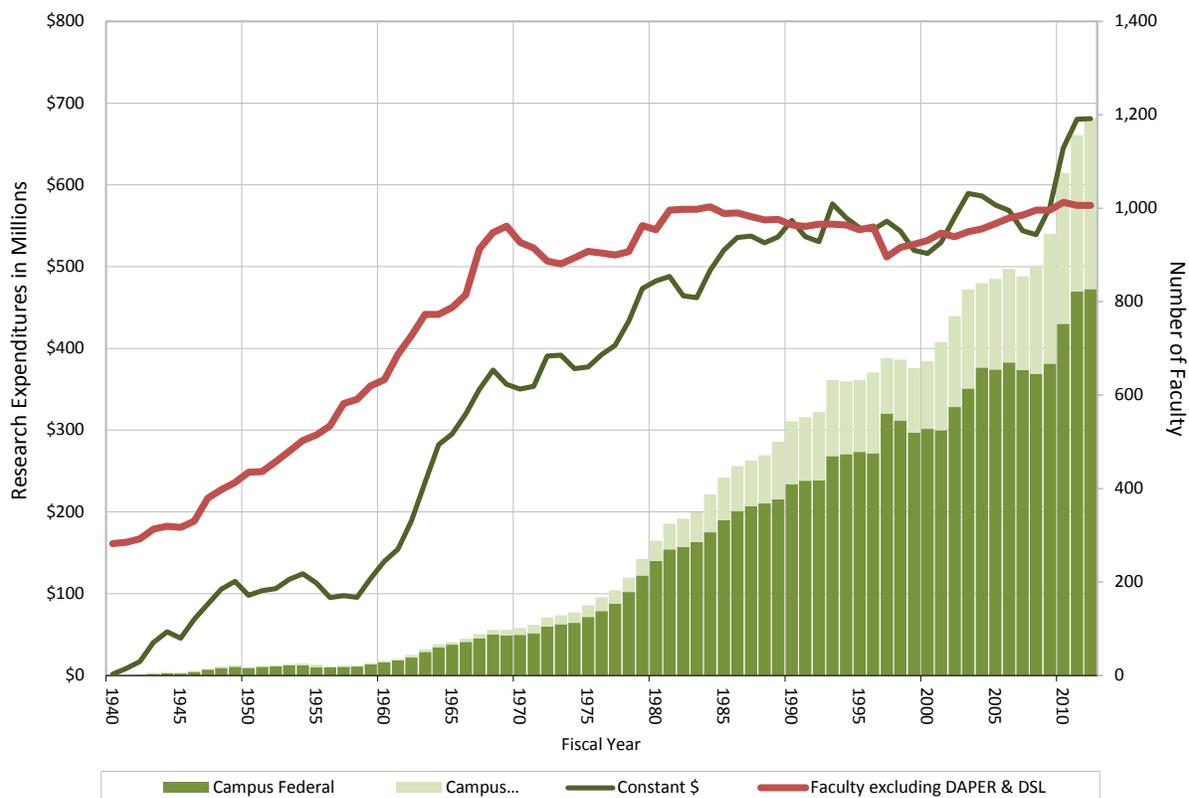
‡Total Research constant dollars are calculated using the Consumer Price Index for all Urban Consumers weighted with fiscal year 2012 equaling 100.

The Institute provides the faculty with the infrastructure and support necessary to conduct research, much of it through contracts, grants, and other arrangements with government, industry, and foundations. The Office of Sponsored Programs provides central support related to the administration of sponsored research programs, and it assists faculty, other principal investigators, and their local administrators in managing and identifying resources for individual sponsored projects. In addition, a Research Council—which is chaired by the Vice President for Research and composed of the heads of all major research laboratories and centers that report to the Vice President for Research—addresses research policy and administration issues.

The Resource Development Office is available to work with faculty to generate proposals for foundation or other private support.

The Institute sees profound merit in a policy of open research and free interchange of information among scholars. At the same time, MIT is committed to acting responsibly and ethically in all its research activities. As a result, MIT has policies related to the suitability of research projects, research conduct, sources of support, use of human subjects, sponsored programs, relations with intelligence agencies, the acquisition of art and artifacts, the disposition of equipment, and collaborations with research-oriented industrial organizations. These policies are spelled out on the Policies and Procedures website and on the Office of Sponsored Programs website.

Campus Research Expenditures and Faculty Excluding Broad and Defense Labs 1940–2012



DAPER: Department of Athletics, Physical Education and Recreation
 DSL: Division of Student Life

Campus Research Sponsors

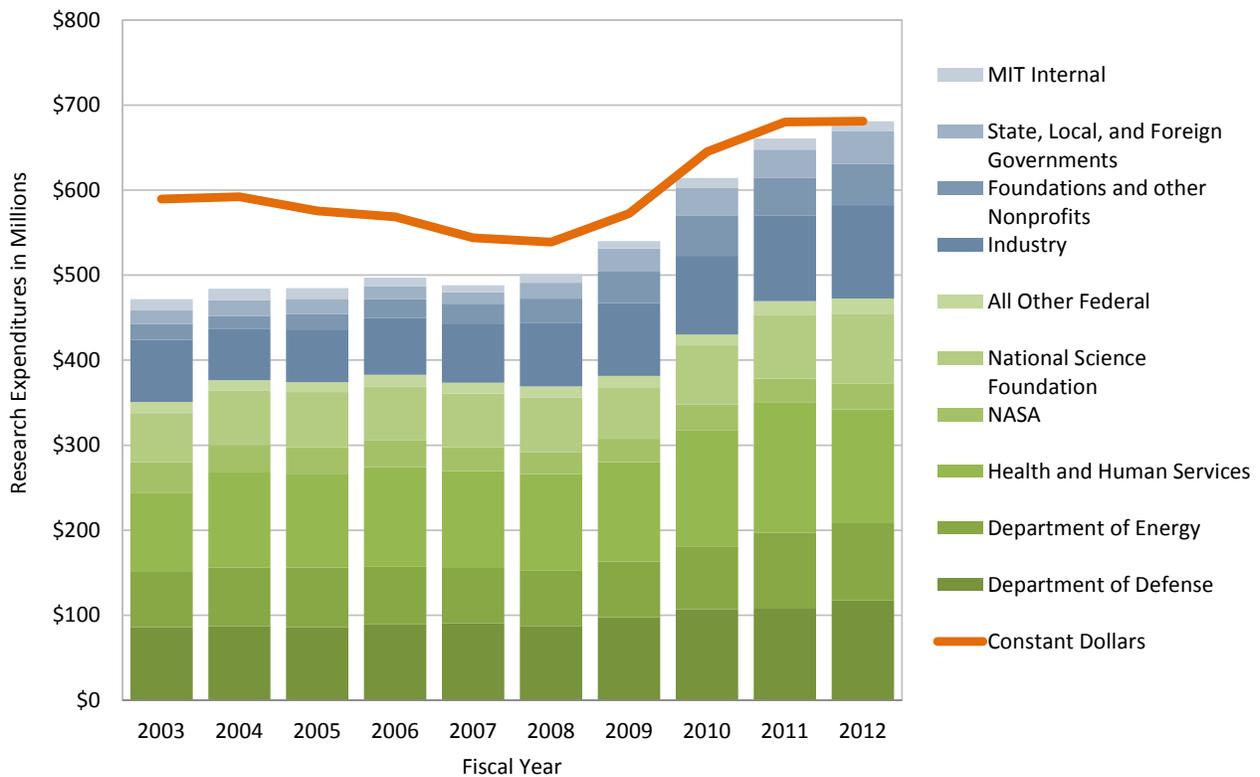
The tables and charts for campus research expenditures below, and on the following pages, show the amount MIT expended by fiscal year (July 1–June 30). These figures do not include expenditures for MIT Lincoln Laboratory. Information for Lincoln Laboratory

begins on page 66. Expenditures funded by industrial sponsors are shown on page 83 in the MIT and Industry section. Federal research expenditures include all primary contracts and grants, including sub-awards from other organizations where the federal government is the original funding source.

**Campus Research Expenditures (in U.S. Dollars)
Fiscal Years 2003–2012**

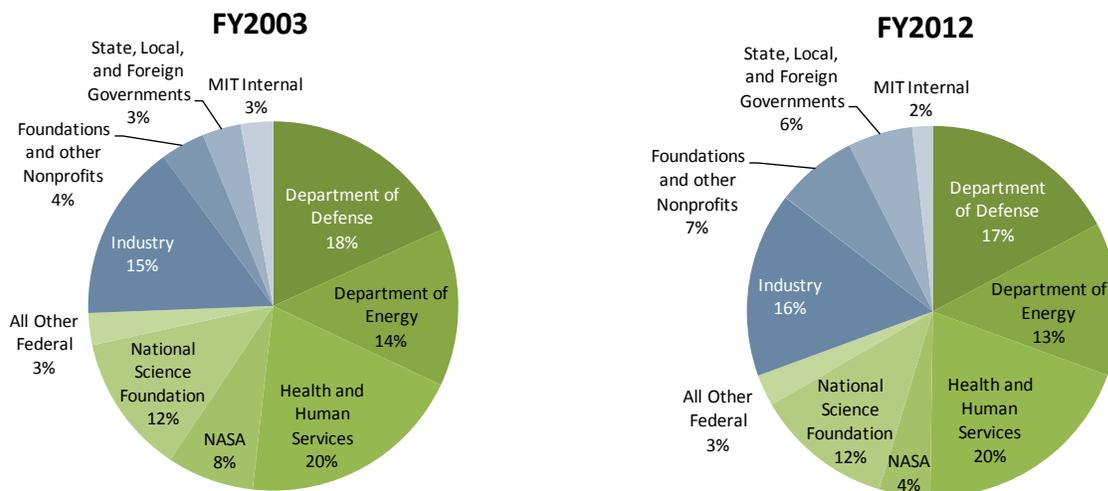
	2003	2004	2005	2006	2007
Federal	350,897,272	376,476,261	374,103,793	382,784,774	373,603,371
Non-federal	120,857,180	107,672,988	110,675,892	114,361,780	114,389,201
Total	471,754,452	484,149,249	484,779,685	497,146,554	487,992,571
Constant dollars*	589,510,002	592,048,558	575,501,115	568,531,503	543,994,740

	2008	2009	2010	2011	2012
Federal	369,008,780	381,459,466	430,154,479	469,520,579	472,582,743
Non-federal	132,487,316	158,595,887	184,216,417	191,304,692	208,496,567
Total	501,496,096	540,055,353	614,370,896	660,825,271	681,079,310
Constant dollars*	539,072,583	572,527,950	645,069,350	680,186,642	681,079,310



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2012 equaling 100.

Campus Research Expenditures by Primary Sponsor



Campus Research Expenditures by Primary Sponsor

Primary Sponsor	FY2012 (in U.S. Dollars)	Percent of Campus Total
Department of Defense	117,457,789	17
Department of Energy	90,940,035	13
Health and Human Services	133,687,332	20
NASA	30,203,575	4
National Science Foundation	81,487,208	12
All other federal	18,806,804	3
Total Federal	472,582,743	69
Industry	109,744,829	16
Foundations and other nonprofits	48,373,460	7
State, local, and foreign governments	38,272,515	6
MIT internal	12,105,763	2
Total Non-Federal	208,496,567	31
Campus Total	681,079,310	100

Department of Defense

Selected Projects

MIT “cheetah” robot rivals running animals in efficiency

A 70-pound “cheetah” robot designed by MIT researchers, including Sangbae Kim, may soon outpace its animal counterparts in running efficiency: In treadmill tests, the researchers have found that the robot—about the size and weight of an actual cheetah—wastes very little energy as it trots continuously for up to an hour and a half at 5 mph. The key to the robot’s streamlined stride: lightweight electric motors, set into its shoulders, that produce high torque with very little heat wasted.

To test the efficiency of the robot, the researchers ran it on a treadmill at a steady 5 mph clip. They measured the voltage and current of the battery, as well as that from each motor. They calculated the robot’s efficiency of locomotion—also known as cost of transport—and found that it was more efficient than robotic competitors such as Boston Dynamic’s Big Dog and Honda’s two-legged robot, ASIMO.

Currently, the team is assembling a set of new motors, designed by Jeffrey Lang. Kim expects that once the group outfits the robot with improved motors, the cheetah robot will be able to gallop at speeds of up to 35 mph. The researchers are convinced that this approach can exceed biological muscle in many aspects, including power, torque and responsiveness.

This research was funded by the Defense Advanced Research Projects Agency’s Maximum Mobility and Manipulation (M3) program.

<http://web.mit.edu/newsoffice/2013/mit-cheetah-robot-0308.html>

One-two punch knocks out aggressive breast cancer cells

Doctors have long known that treating patients with multiple cancer drugs often produces better results than treatment with just a single drug. Now, a study shows that the order and timing of drug administration can have a dramatic effect. Researchers, led by Michael Yaffe who is a member of the David H. Koch Institute for Integrative Cancer Research at MIT, are now working with researchers at Dana-Farber Cancer Institute to plan clinical trials of the staggered drug therapy. Both drugs—erlotinib and doxorubicin—are already approved for cancer treatment.

In a paper, published in *Cell*, the researchers showed that staggering the doses of two specific drugs dramatically boosts their ability to kill a particularly malignant type of breast cancer cells. Postdoc Michael Lee was lead author of the paper.

The research was funded by the National Institutes of Health Integrative Cancer Biology Program and the Department of Defense.

<http://web.mit.edu/newsoffice/2012/dual-drug-order-chemotherapy-0511.html>

Decoding the structure of bone

The bones that support our bodies are made of remarkably complex arrangements of materials—so much so that decoding the precise structure responsible for their great strength and resilience has eluded scientists’ best efforts for decades. A team of researchers, led by Markus Buehler, have finally unraveled the structure of bone with almost atom-by-atom precision, after many years of analysis by some of the world’s most powerful computers and comparison with laboratory experiments to confirm the computed results.

Buehler says the riddle was to find how two different materials—a soft, flexible biomolecule called collagen and a hard, brittle form of the mineral apatite—combine to form something that is simultaneously hard, tough and slightly flexible. One key they found, is that the hydroxyapatite grains are tiny, thin platelets deeply embedded in the collagen matrix. The two constituents are bound together by electrostatic interactions, which allow them to slip somewhat against each other without breaking. Ultimately, this work could lead to the synthesis of new bone-like materials, either as biomedical materials to substitute for bone or as new structural materials for engineering uses.

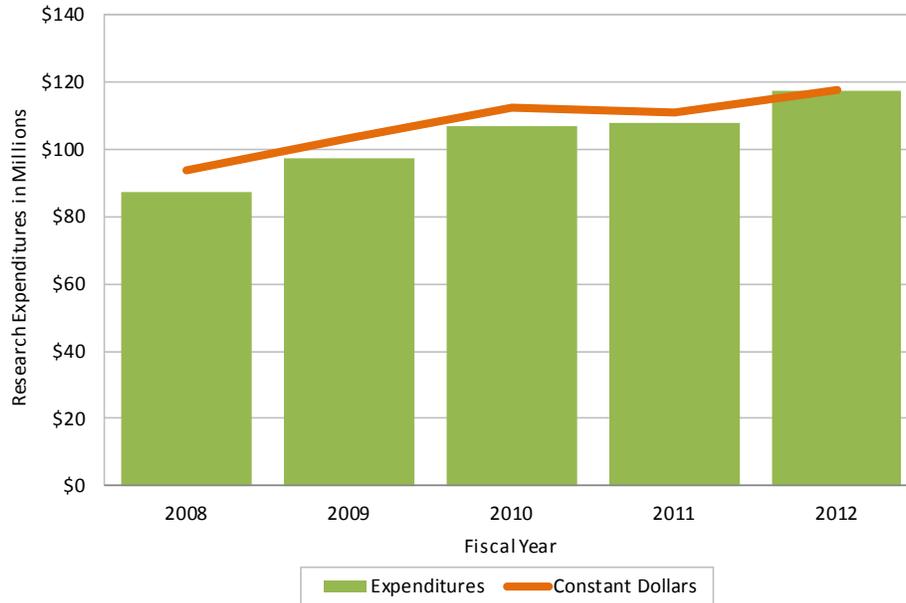
Postdoc Arun Nair was the first author of the paper, with graduate student Shu-Wei Chang, postdoc Alfonso Gautieri, and Markus Buehler.

The work was supported by the Office of Naval Research, the Army Research Office, the National Science Foundation, and the MIT-Italy Program. The research used high-performance computing resources from NSF’s XSEDE program, the CILEA Consortium, the LISA Initiative, and the IS CRA Initiative

<http://web.mit.edu/newsoffice/2013/decoding-the-structure-of-bone-0416.html>

**Department of Defense Campus Research Expenditures (in U.S. Dollars)
Fiscal Years 2008–2012**

	2008	2009	2010	2011	2012
Campus research	87,369,845	97,528,094	106,890,338	107,753,196	117,457,789
Constant dollars*	93,916,360	103,392,290	112,231,360	110,910,233	117,457,789



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2012 equaling 100.

**Leading Departments, Laboratories, and Centers
Receiving Support in Fiscal Year 2012**
(shown in descending order of expenditures)

- Research Laboratory of Electronics
- Computer Science and Artificial Intelligence Laboratory
- Institute for Soldier Nanotechnologies
- Microsystems Technology Laboratories
- Mechanical Engineering
- Aeronautics and Astronautics
- Plasma Science and Fusion Center
- Laboratory for Information and Decision Systems
- Media Laboratory
- McGovern Institute for Brain Research

In fall 2012, the Department of Defense funded the primary appointments of graduate students with 338 research assistantships and 84 fellowships.

Twenty-eight current faculty and staff have received the Office of Naval Research Young Investigator Program Award.

Department of Energy

Selected Projects

One order of steel; hold the greenhouse gases

Anyone who has seen pictures of the giant, red-hot cauldrons in which steel is made—fed by vast amounts of carbon, and belching flame and smoke—would not be surprised to learn that steelmaking is one of the world’s leading industrial sources of greenhouse gases. But remarkably, a new process developed by MIT researchers could change all that.

The new process even carries a couple of nice side benefits: The resulting steel should be of higher purity, and eventually, once the process is scaled up, cheaper. Donald Sadoway, senior author of a new paper describing the process, says this could be a significant “win, win, win” proposition. The paper, co-authored by Antoine Allanore, and former postdoc Lan Yin, has been published in the journal *Nature*.

The idea for the new method, Sadoway says, arose when he received a grant from NASA to look for ways of producing oxygen on the moon—a key step toward future lunar bases. Sadoway found that a process called molten oxide electrolysis could use iron oxide from the lunar soil to make oxygen in abundance, with no special chemistry. He tested the process using lunar-like soil from Meteor Crater in Arizona finding that it produced steel as a by-product.

The research was supported by the American Iron and Steel Institute and the U.S. Department of Energy.

<http://web.mit.edu/newsoffice/2013/steel-without-greenhouse-gas-emissions-0508.html>

‘Invisibility’ could be a key to better electronics

A new approach that allows objects to become “invisible” has now been applied to an entirely different area: letting particles “hide” from passing electrons, which could lead to more efficient thermoelectric devices and new kinds of electronics.

The concept—developed by graduate student Bolin Liao, former postdoc Mona Zebarjadi, research scientist Keivan Esfarjani, and Gang Chen—is described in a paper in the journal *Physical Review Letters*. The researchers’ initial impetus was to optimize the materials used in thermoelectric devices, which produce an electrical current from a temperature gradient. Such

devices require a combination of characteristics that are hard to obtain: high electrical conductivity (so the generated current can flow freely), but low thermal conductivity (to maintain a temperature gradient). The team’s simulations show this electron-cloaking material could meet these requirements unusually well.

This research was funded by the U.S. Department of Energy through MIT’s Solid-State Solar-Thermal Energy Conversion center, a DoE Energy Frontier Research Center.

<http://web.mit.edu/newsoffice/2012/invisibility-core-shell-nanoparticles-1012.html>

MIT researchers discover a new kind of magnetism

Following up on earlier theoretical predictions, MIT researchers have now demonstrated experimentally the existence of a fundamentally new kind of magnetic behavior, adding to the two previously known states of magnetism.

Ferromagnetism is the simple magnetism of a bar magnet or compass needle. In a second type of magnetism, antiferromagnetism, the magnetic fields of the ions within a metal or alloy cancel each other out. The prediction and discovery of antiferromagnetism won Nobel Prizes for French physicist Louis Neel in 1970 and for Clifford Shull in 1994.

The experimental work showing the existence of this new state, called a quantum spin liquid (QSL), is reported in the journal *Nature*, with Young Lee as the senior author and Tianheng Han PhD 2012, as lead author. The QSL is a solid crystal, but its magnetic state is described as liquid: Unlike the other two kinds of magnetism, the magnetic orientations of the individual particles within it fluctuate constantly, resembling the constant motion of molecules within a true liquid.

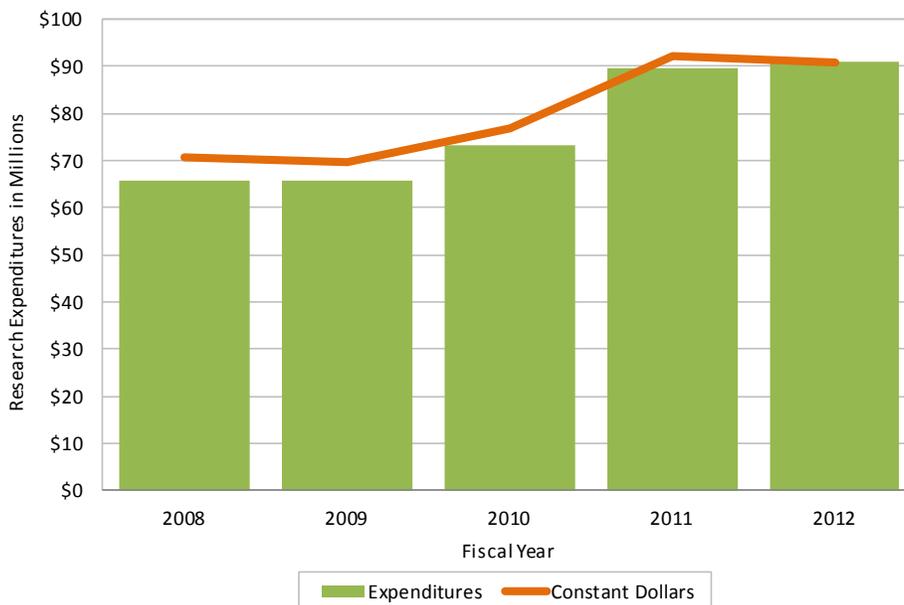
In addition to Lee and Han, the work was carried out by J.S. Helton of NIST, research scientist Shaoyan Chu, Daniel Nocera, Jose Rodriguez-Rivera of NIST and the University of Maryland, and Colin Broholm of Johns Hopkins University.

The work was supported by the U.S. Department of Energy and the National Science Foundation.

<http://web.mit.edu/newsoffice/2012/mit-researchers-discover-a-new-kind-of-magnetism-1219.html>

**Department of Energy Campus Research Expenditures (in U.S. Dollars)
Fiscal Years 2008–2012**

	2008	2009	2010	2011	2012
Campus research	65,610,631	65,773,294	73,273,733	89,562,126	90,940,035
Constant dollars*	70,526,755	69,728,128	76,935,023	92,186,186	90,940,035



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2012 equaling 100.

**Leading Departments, Laboratories, and Centers
Receiving Support in Fiscal Year 2012**

(shown in descending order of expenditures)

- Plasma Science and Fusion Center
- Laboratory for Nuclear Science
- Materials Processing Center
- Research Laboratory of Electronics
- Nuclear Science and Engineering
- Mechanical Engineering
- Chemical Engineering
- Materials Science and Engineering
- Nuclear Reactor Laboratory
- Center for Global Change Science

In fall 2012, the Department of Energy funded the primary appointments of graduate students with 232 research assistantships, two teaching assistantships, and 23 fellowships.

Twenty-two current faculty have received the Department of Energy Outstanding Junior Investigator award or Early Career Research Program Award.

Department of Health and Human Services

Selected Projects

MIT team builds most complex synthetic biology circuit yet

Using genes as interchangeable parts, synthetic biologists design cellular circuits that can perform new functions, such as sensing environmental conditions. However, the complexity that can be achieved in such circuits has been limited by a critical bottleneck: the difficulty in assembling genetic components that don't interfere with each other.

Unlike electronic circuits on a silicon chip, biological circuits inside a cell cannot be physically isolated from one another. Christopher Voigt and his students have now developed circuit components that don't interfere with one another, allowing them to produce the most complex synthetic circuit ever built. The circuit, described in *Nature*, integrates four sensors for different molecules. Such circuits could be used in cells to precisely monitor their environments and respond appropriately.

Lead author of the paper is former postdoc Tae Seok Moon, now an assistant professor at Washington University in St. Louis. Other authors are postdocs Chunbo Lou and Brynne Stanton, and University of California at San Francisco graduate student Alvin Tamsir.

The research was funded by the U.S. Office of Naval Research, the National Institutes of Health, Life Technologies, Defense Advanced Research Projects Agency and the National Science Foundation.

<http://web.mit.edu/newsoffice/2012/complex-biological-circuit-1007.html>

New material harvests energy from water vapor

MIT engineers have created a new polymer film that can generate electricity by drawing on a ubiquitous source: water vapor. The new material changes its shape after absorbing tiny amounts of evaporated water, allowing it to repeatedly curl up and down. Harnessing this continuous motion could drive robotic limbs or generate enough electricity to power micro- and nanoelectronic devices, such as environmental sensors.

Mingming Ma, a postdoc at MIT's David H. Koch Institute for Integrative Cancer Research, is lead author of a paper describing the new material in *Science*.

Robert Langer, David H. Koch Institute Professor at MIT, is senior author. Other authors are Koch Institute postdoc Liang Guo and professor Daniel Anderson, a member of the Koch Institute and MIT's Institute for Medical Engineering and Science.

The research was funded by the National Heart, Lung, and Blood Institute Program of Excellence in Nanotechnology, the National Cancer Institute, and the Armed Forces Institute of Regenerative Medicine.

<http://web.mit.edu/newsoffice/2013/new-material-harvests-energy-from-water-vapor-0110.html>

Engineering cells for more efficient biofuel production

In the search for renewable alternatives to gasoline, heavy alcohols such as isobutanol are promising candidates. Not only do they contain more energy than ethanol, but they are also more compatible with existing gasoline-based infrastructure. For isobutanol to become practical, however, scientists need a way to reliably produce huge quantities of it from renewable sources. MIT chemical engineers and biologists have now devised a way to dramatically boost isobutanol production in yeast, which naturally make it in small amounts. They engineered yeast so that isobutanol synthesis takes place entirely within mitochondria, cell structures that generate energy and also host many biosynthetic pathways. Using this approach, they were able to boost isobutanol production by about 260 percent.

Though still short of the scale needed for industrial production, the advance suggests that this is a promising approach to engineering not only isobutanol but other useful chemicals as well, says Gregory Stephanopoulos, one of the senior authors of a paper describing the work in *Nature Biotechnology*.

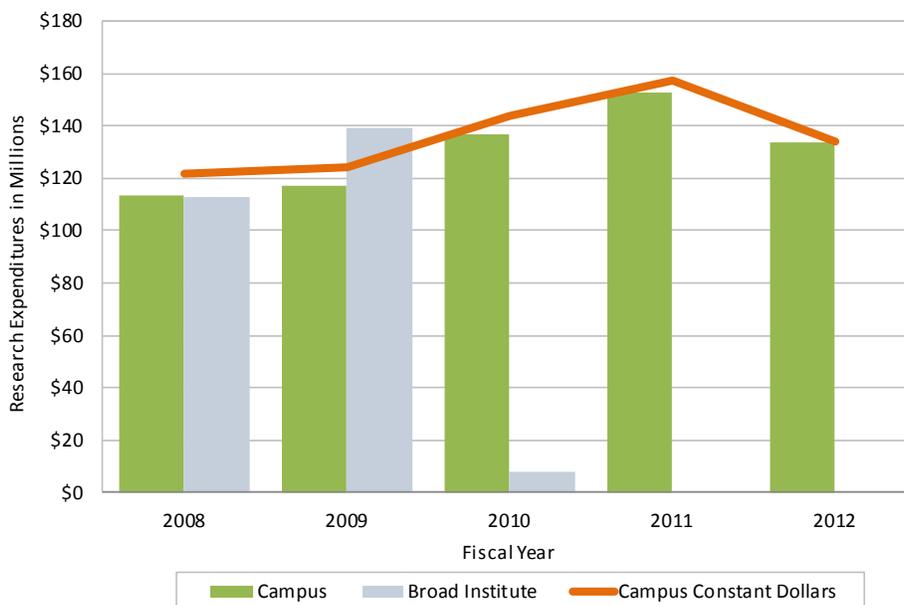
Stephanopoulos collaborated with Professor Gerald Fink, member of the Whitehead Institute, on this research. The lead author of the paper is Jose Avalos, a postdoc at the Whitehead Institute and MIT.

The research was funded by the National Institutes of Health and Shell Global Solutions.

<http://web.mit.edu/newsoffice/2013/yeast-research-may-boost-biofuel-production-efficiency-0217.html>

**Department of Health and Human Services (HHS)
Campus and Broad Institute Research Expenditures (in U.S. Dollars)*
Fiscal Years 2008–2012**

	2008	2009	2010	2011	2012
Campus research	113,348,419	116,960,155	136,923,238	152,664,013	133,687,332
Broad Institute research	112,958,244	138,935,579	7,637,672	0	0
Total HHS	226,306,663	255,895,734	144,560,910	152,664,013	133,687,332
Constant dollars†	243,263,543	271,282,303	151,784,228	157,136,882	133,687,332



*The Broad Institute separated from MIT on July 1, 2009 and no longer receives funding through MIT. The chart above displays both MIT campus research expenditures and Broad Institute research expenditures funded through MIT.

†Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2012 equaling 100.

**Leading Departments, Laboratories, and Centers
Receiving Support in Fiscal Year 2012**

(shown in descending order of expenditures)

- Koch Institute for Integrative Cancer Research
- Biology
- Chemistry
- Biological Engineering
- Harvard/MIT Division of Health Sciences
and Technology
- Center for Environmental Health Sciences
- Picower Institute for Learning and Memory
- McGovern Institute for Brain Research
- Computer Science and Artificial
Intelligence Laboratory
- Research Laboratory of Electronics

In fall 2012, the Department of Health and Human Services, including the National Institutes of Health, funded the primary appointments of graduate students with 151 research assistantships and 101 fellowships.

Nine current faculty have received the NIH Director’s Pioneer Award. The recipients are Emery Brown, Arup Chakraborty, Hidde Ploegh, Aviv Regev, Leona Samson, Alice Ting, Alexander van Oudenaarden, Mehmet Yanik, and Feng Zhang.

NASA

Selected Projects

Scientists discover water ice on Mercury

Mercury, the smallest and innermost planet in our solar system, revolves around the sun in a mere 88 days, making a tight orbit that keeps the planet incredibly toasty. Surface temperatures on Mercury can reach a blistering 800 degrees Fahrenheit—hot enough to liquefy lead. Researchers from NASA, MIT, the University of California at Los Angeles and elsewhere have discovered evidence that the scorching planet may harbor pockets of water ice, along with organic material, in several permanently shadowed craters near Mercury's north pole.

“We thought the most exciting finding could be that this really was water ice,” says Maria Zuber, a member of the research team. “But the identification of darker, insulating material that may indicate complex organics makes the story even more thrilling.”

To get a clearer picture of Mercury's polar regions, Zuber and her colleagues analyzed observations taken by NASA's MESSENGER (MErcury Surface, Space ENvironment, GEochemistry and Ranging) mission, a probe that has been orbiting the planet and mapping its topography since April 2011. MESSENGER will continue to orbit Mercury, and Zuber says future data may reveal information beyond the planet's surface. “There are still some really good questions to answer about the interior,” Zuber says. “I'll tell you, we're not done.”

<http://web.mit.edu/newsoffice/2012/scientists-discover-water-ice-on-mercury-1129.html>

GRAIL reveals a battered lunar history

Beneath its heavily pockmarked surface, the moon's interior bears remnants of the very early solar system. Unlike Earth, where plate tectonics has essentially erased any trace of the planet's earliest composition, the moon's interior has remained relatively undisturbed over billions of years, preserving a record in its rocks of processes that occurred in the solar system's earliest days.

Now scientists at MIT, NASA, the Jet Propulsion Laboratory and elsewhere have found evidence that, beneath its surface, the moon's crust is almost completely pulverized. The finding suggests that, in its first billion years, the moon—and probably other planets like Earth—may have endured much more fracturing from massive impacts than previously thought.

The startling observations come from data collected by NASA's Gravity Recovery and Interior Laboratory (GRAIL) mission. From GRAIL's measurements, planetary scientists have now stitched together a high-resolution map of the moon's gravity—a force created by surface structures such as mountains and craters, as well as deeper structures below the surface. The resulting map reveals an interior gravitational field consistent with an incredibly fractured lunar crust. Maria Zuber leads the GRAIL mission.

<http://web.mit.edu/newsoffice/2012/grail-reveals-a-battered-lunar-history-1205.html>

NASA selects MIT-led TESS project for 2017 mission

Following a three-year competition, NASA has selected the Transiting Exoplanet Survey Satellite (TESS) project at MIT for a planned launch in 2017. The space agency announced the mission—to be funded by a \$200 million grant to the MIT-led team—in April 2013.

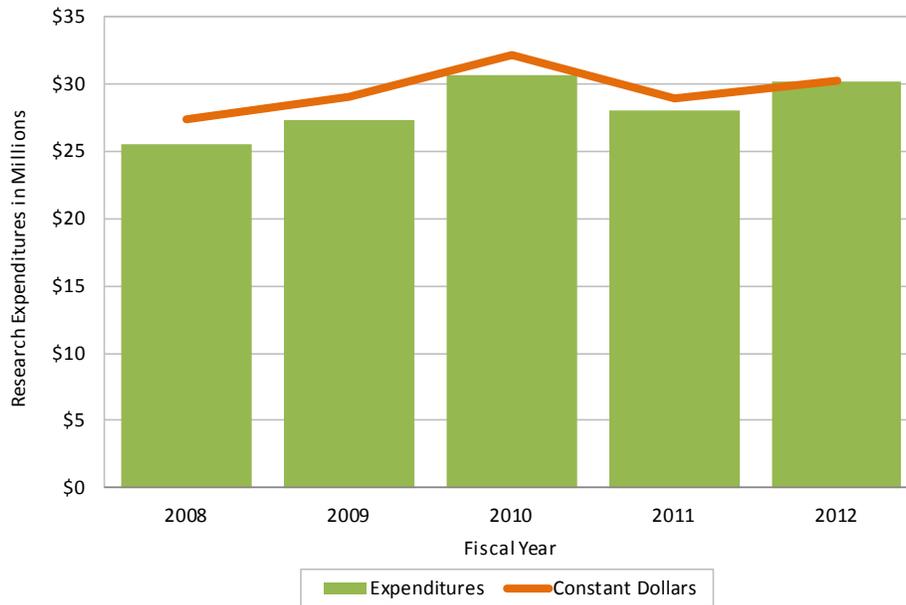
TESS team partners include the MIT Kavli Institute for Astrophysics and Space Research (MKI) and MIT Lincoln Laboratory; NASA's Goddard Spaceflight Center; Orbital Sciences Corporation; NASA's Ames Research Center; the Harvard-Smithsonian Center for Astrophysics; The Aerospace Corporation; and the Space Telescope Science Institute.

The project, led by principal investigator George Ricker, a senior research scientist at MKI, will use an array of wide-field cameras to perform an all-sky survey to discover transiting exoplanets, ranging from Earth-sized planets to gas giants, in orbit around the brightest stars in the sun's neighborhood.

<http://web.mit.edu/newsoffice/2013/nasa-selects-tess-for-mission-0405.html>

**NASA Campus Research Expenditures (in U.S. Dollars)
Fiscal Years 2008–2012**

	2008	2009	2010	2011	2012
Campus research	25,479,571	27,358,036	30,629,006	28,079,693	30,203,575
Constant dollars*	27,388,724	29,003,028	32,159,455	28,902,394	30,203,575



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2012 equaling 100.

**Leading Departments, Laboratories, and Centers
Receiving Support in Fiscal Year 2012**
(shown in descending order of expenditures)

- Kavli Institute for Astrophysics and Space Research
- Earth, Atmospheric, and Planetary Sciences
- Aeronautics and Astronautics
- Earth System Initiative
- Haystack Observatory
- Center for Global Change Science
- Research Laboratory of Electronics
- Harvard/MIT Division of Health Sciences
and Technology
- Mechanical Engineering
- Institute for Soldier Nanotechnologies

In fall 2012, NASA funded the primary appointments of graduate students with 60 research assistantships and 12 fellowships.

National Science Foundation

Selected Projects

Funneling the sun's energy

The quest to harness a broader spectrum of sunlight's energy to produce electricity has taken a radically new turn with the proposal of a "solar energy funnel" that takes advantage of materials under elastic strain. Ju Li is a corresponding author of a paper describing the new solar-funnel concept that was published in the journal *Nature Photonics*.

In this case, the "funnel" is a metaphor: Electrons and their counterparts, holes—which are split off from atoms by the energy of photons—are driven to the center of the structure by electronic forces, not by gravity. As it happens, the material actually does assume the shape of a funnel: It is a stretched sheet of vanishingly thin material, poked down at its center by a microscopic needle that indents the surface and produces a curved, funnel-like shape. The pressure exerted by the needle imparts elastic strain, which increases toward the sheet's center. The varying strain changes the atomic structure just enough to "tune" different sections to different wavelengths of light—including not just visible light, but also some of the invisible spectrum, which accounts for much of sunlight's energy.

The work was done with Ji Feng of Peking University and Cheng-Wei Huang, and was supported by the U.S. National Science Foundation, the U.S. Air Force Office of Scientific Research, and the National Natural Science Foundation of China.

<http://web.mit.edu/newsoffice/2012/funneling-the-suns-energy-1125.html>

Storing data in individual molecules

In 1980, a hard drive could store about a half-megabyte of data in a square inch of disk space; now, manufacturers are closing in on a million megabytes of data per square inch. An experimental technology called molecular memory, which would store data in individual molecules, promises another 1,000-fold increase in storage density. In *Nature*, an international team of researchers led by senior research scientist Jagadeesh Moodera, describes a new molecular-memory scheme.

Moreover, where previous schemes required sandwiching the storage molecules between two ferromagnetic electrodes, the new scheme would require only one ferromagnetic electrode. That could greatly simplify manufacture.

The research was funded by the Office of Naval Research and by the National Science Foundation.

<http://web.mit.edu/newsoffice/2013/storing-data-in-individual-molecules.html>

MIT researchers improve quantum dot performance

Quantum dots—tiny particles that emit light in a dazzling array of glowing colors—have the potential for many applications, but have faced a series of hurdles to improved performance. First discovered in the 1980s, these materials have been the focus of intense research because of their potential to provide significant advantages in a wide variety of optical applications, but their actual usage has been limited by several factors. Research published in the journal *Nature Materials* by postdoc Ou Chen, Mounqi Bawendi, and several others raises the prospect that these limiting factors can all be overcome.

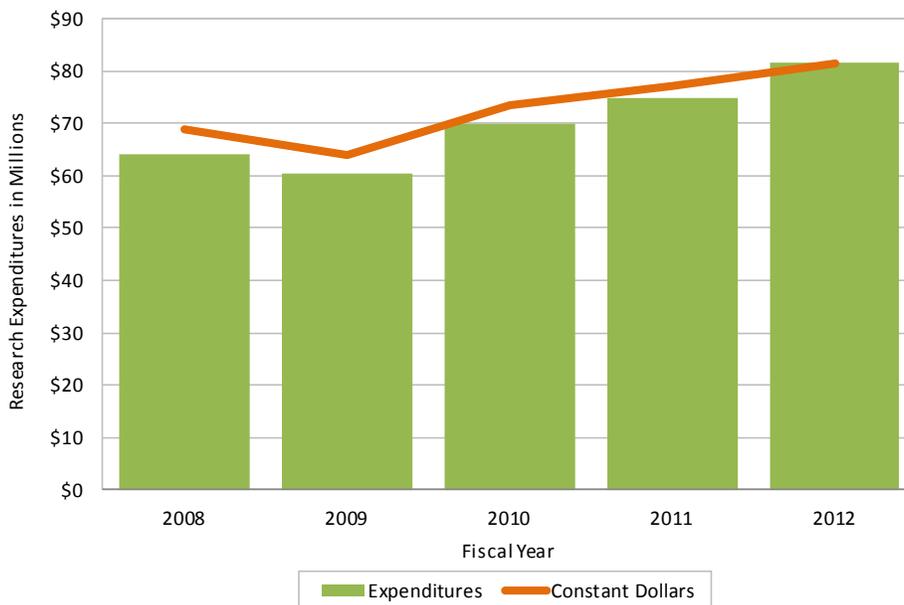
The new process developed by the MIT team produces quantum dots with four important qualities: uniform sizes and shapes; bright emissions, producing close to 100 percent emission efficiency; a very narrow peak of emissions, meaning that the colors emitted by the particles can be precisely controlled; and an elimination of a tendency to blink on and off, which limited the usefulness of earlier quantum dot applications.

In addition to Chen and Bawendi, the team included seven other students and postdocs and two researchers from Massachusetts General Hospital and Harvard Medical School. The work was supported by the National Institutes of Health, the Army Research Office through MIT's Institute for Soldier Nanotechnologies, and by the National Science Foundation through the Collaborative Research in Chemistry Program.

<http://web.mit.edu/newsoffice/2013/mit-researchers-improve-quantum-dot-performance-0203.html>

**National Science Foundation Campus Research Expenditures (in U.S. Dollars)
Fiscal Years 2008–2012**

	2008	2009	2010	2011	2012
Campus research	63,950,370	60,394,853	69,801,369	74,859,339	81,487,208
Constant dollars*	68,742,093	64,026,291	73,289,155	77,052,626	81,487,208



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2012 equaling 100.

**Leading Departments, Laboratories, and Centers
Receiving Support in Fiscal Year 2012**
(shown in descending order of expenditures)

- Computer Science and Artificial Intelligence Laboratory
- Earth, Atmospheric, and Planetary Sciences Research Laboratory of Electronics
- Biological Engineering
- Kavli Institute for Astrophysics and Space Research
- Mathematics
- Haystack Observatory
- Chemistry
- Mechanical Engineering
- Center for Materials Science and Engineering

In fall 2012, the National Science Foundation funded the primary appointments of graduate students with 281 research assistantships and 299 fellowships.

The National Science Foundation has awarded Faculty Early Career Development (CAREER) Awards to 138 current faculty and staff members.

Other Federal Agencies

Selected Projects

MIT selected by U.S. Department of Transportation to lead New England Consortium on Transportation Safety & Livable Communities

The Engineering Systems Division's Center for Transportation & Logistics has been selected to lead the U.S. Department of Transportation Research & Innovative Technology Administration University Transportation Center for the New England Region. The University Transportation Centers Program (UTC) strives to advance research and education programs that address critical transportation challenges facing our nation. The UTCs, which are located throughout the United States, conduct research that directly supports the priorities of the U.S. Department of Transportation, and the participating universities are a critical part of the nation's transportation strategy.

The two-year \$3.5 million grant funds transportation and education programs at MIT and its regional partners that include the University of Connecticut, Harvard University, and the Universities of Maine and Massachusetts. Joseph Coughlin led the proposal and is principal investigator of the grant establishing the New England University Transportation Center. The grant will support surface transportation research and education projects in the area of safety and livable communities with special attention given to the role of new technologies and disadvantaged populations such as the elderly.

<http://web.mit.edu/press/2012/agelab-dot-grant.html>

Study: At most a third of us show a consistent approach to financial risk

In economics, classical theory holds that we have consistent risk preferences, regardless of the precise decision, from investments to insurance programs and retirement plans. But studies in behavioral economics indicate that people's choices can vary greatly depending on the subject matter and circumstances of each decision.

Now a new paper co-authored by Amy Finkelstein brings a large dose of empirical data to the problem, by looking at the way tens of thousands of Americans have handled risk in selecting health insurance and retirement plans. The study, published in the *American Economic Review*, finds that at most 30 percent of us make consistent decisions about financial risk across a variety of areas.

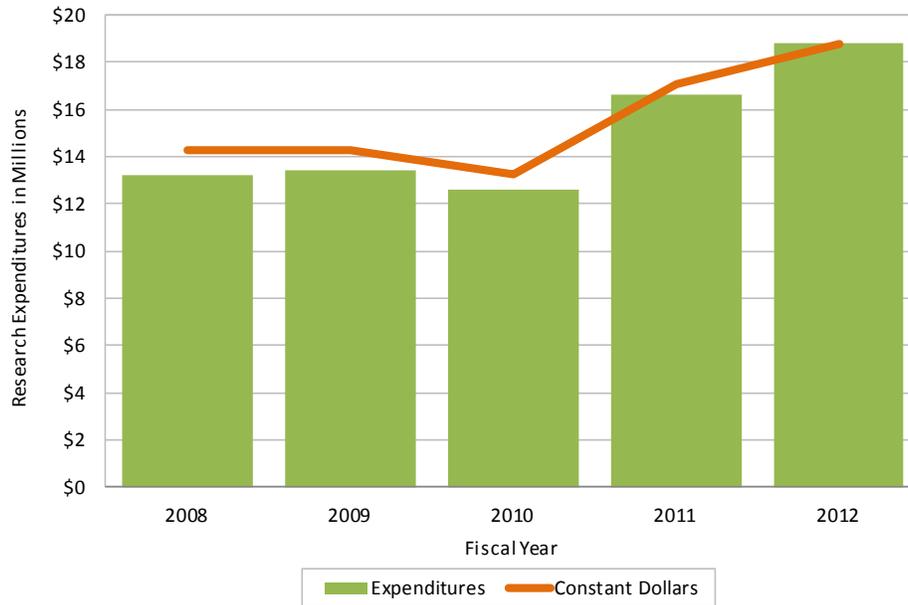
Finkelstein suggests the study can be useful for social scientists or policymakers who build models or construct programs that make assumptions about risk tolerance; now those models can include more specific estimates of the ways people bear risk.

Research for the current paper was funded by the National Institute of Aging, the National Science Foundation, the U.S. Social Security Administration, the Sloan Foundation, and the MacArthur Foundation.

<http://web.mit.edu/newsoffice/2012/study-only-a-third-of-us-show-consistent-approach-to-financial-risk-1203.html>

**Other Federal Agencies Campus Research Expenditures (in U.S. Dollars)
Fiscal Years 2008–2012**

	2008	2009	2010	2011	2012
Campus research	13,249,945	13,445,035	12,636,795	16,602,212	18,806,804
Constant dollars*	14,242,747	14,253,461	13,268,221	17,088,636	18,806,804



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2012 equaling 100.

Some of the leading other federal agencies providing funding include: Federal Aviation Administration, Intelligence Advanced Research Projects Activity, Department of Transportation, Department of Commerce, Department of Homeland Security, and Environmental Protection Agency.

**Leading Departments, Laboratories, and Centers
Receiving Support in Fiscal Year 2012**

(shown in descending order of expenditures)

- Aeronautics and Astronautics
- Center for Transportation and Logistics
- Computer Science and Artificial Intelligence Laboratory
- Sea Grant College Program
- Center for Global Change Science
- Earth, Atmospheric and Planetary Sciences
- Civil and Environmental Engineering
- Research Laboratory of Electronics
- Sloan School of Management
- Materials Processing Center

In fall 2012, Other Federal Agencies funded the primary appointments of graduate students with 47 research assistantships and six fellowships.

Nonprofit Organizations

Selected Projects

Editing the genome with high precision

Researchers at MIT, the Broad Institute, and Rockefeller University have developed a new technique for precisely altering the genomes of living cells by adding or deleting genes. The researchers say the technology could offer an easy-to-use, less-expensive way to engineer organisms that produce biofuels; to design animal models to study human disease; and to develop new therapies, among other potential applications.

To create their new genome-editing technique, the researchers modified a set of bacterial proteins that normally defend against viral invaders. Using this system, scientists can alter several genome sites simultaneously and can achieve much greater control over where new genes are inserted, says Feng Zhang, leader of the research team.

The research was funded by the National Institute of Mental Health; the W.M. Keck Foundation; the McKnight Foundation; the Bill & Melinda Gates Foundation; the Damon Runyon Cancer Research Foundation; the Searle Scholars Program; and philanthropic support from MIT alumni Mike Boylan and Bob Metcalfe, as well as the newscaster Jane Pauley.

<http://web.mit.edu/newsoffice/2013/editing-the-genome-with-high-precision-0103.html>

Exploring a breakdown in communication

One of the defining characteristics of autism is difficulty communicating with others. However, it is unclear whether those struggles arise only from the poor social skills commonly associated with autism, or whether autistic children suffer from more specific linguistic impairments. In a study appearing in the journal *Language Acquisition*, Kenneth Wexler reports that some autistic children do have a specific linguistic deficit: They are unable to understand a specific type of grammatical construction involving reflexive pronouns. This finding suggests that there may be a biological basis for the language impairments seen in autism, and paves the way for genetic studies that could reveal new targets for treating the disease, Wexler says.

Lead author of the paper is former postdoc Alexandra Perovic, now at University College London. Former graduate student and postdoc Nadezhda Modyanova is also an author of the paper.

The research was funded by the Anne and Paul Marcus Family Foundation and the Simons Initiative on Autism and the Brain.

<http://web.mit.edu/newsoffice/2013/autism-language-acquisition-0419.html>

Stacking 2-D materials produces surprising results

Graphene has dazzled scientists, ever since its discovery more than a decade ago, with its unequalled electronic properties, its strength and its light weight. But one long-sought goal has proved elusive: how to engineer into graphene a property called a band gap, which would be necessary to use the material to make transistors and other electronic devices.

New findings by researchers at MIT are a major step toward making graphene with this coveted property. The work could also lead to revisions in some theoretical predictions in graphene physics. The new technique involves placing a sheet of graphene—a carbon-based material whose structure is just one atom thick—on top of hexagonal boron nitride, another one-atom-thick material with similar properties. The resulting material shares graphene's amazing ability to conduct electrons, while adding the band gap necessary to form transistors and other semiconductor devices.

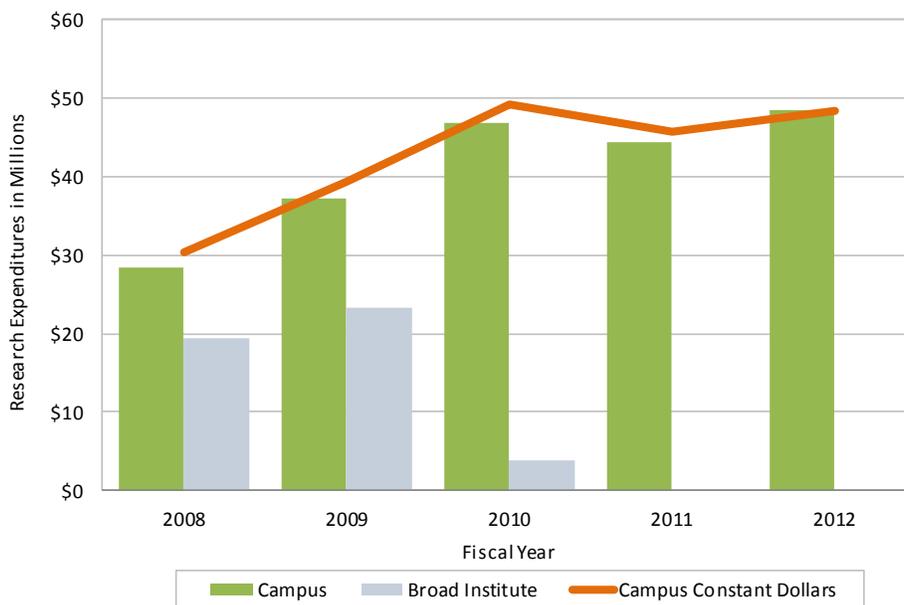
The work is described in a paper in the journal *Science* co-authored by Pablo Jarillo-Herrero, Ray Ashoori, and ten others. The research included postdocs Ben Hunt and Andrea Young, and graduate student Javier Sanchez-Yamagishi, as well as six other researchers from the University of Arizona, the National Institute for Materials Science in Tsukuba, Japan, and Tohoku University in Japan.

The work was funded by the U.S. Department of Energy, the Gordon and Betty Moore Foundation and the National Science Foundation.

<http://web.mit.edu/newsoffice/2013/layered-stacks-could-unleash-graphenes-electronic-potential-0516.html>

**Nonprofit Organizations Campus and Broad Institute Research Expenditures (in U.S. Dollars)*
Fiscal Years 2008–2012**

	2008	2009	2010	2011	2012
Campus research	28,324,003	37,161,950	46,846,106	44,436,470	48,373,460
Broad Institute research	19,370,397	23,376,207	3,792,875	0	0
Total Nonprofit	47,694,400	60,538,156	50,638,981	44,436,470	48,373,460
Constant dollars†	51,268,083	64,178,211	53,169,274	45,738,404	48,373,460



*The Broad Institute separated from MIT on July 1, 2009 and no longer receives funding through MIT. The chart above displays both MIT campus research expenditures and Broad Institute research expenditures funded through MIT.

†Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2012 equaling 100.

Leading Departments, Laboratories, and Centers

Receiving Support in Fiscal Year 2012

(shown in descending order of expenditures)

- Masdar Institute of Science and Technology
- Mechanical Engineering
- Economics
- McGovern Institute for Brain Research
- Brain and Cognitive Sciences
- MIT-Singapore University of Technology
and Design Collaboration
- Civil and Environmental Engineering
- MIT Energy Initiative
- Earth System Initiative
- Koch Institute for Integrative Cancer Research

Broad Institute of Harvard and MIT

The Broad Institute is founded on two principles—that this generation has a historic opportunity and responsibility to transform medicine, and that to fulfill this mission, we need new kinds of research institutions with a deeply collaborative spirit across disciplines and organizations. Operating under these principles, the Broad Institute is committed to meeting the most critical challenges in biology and medicine.

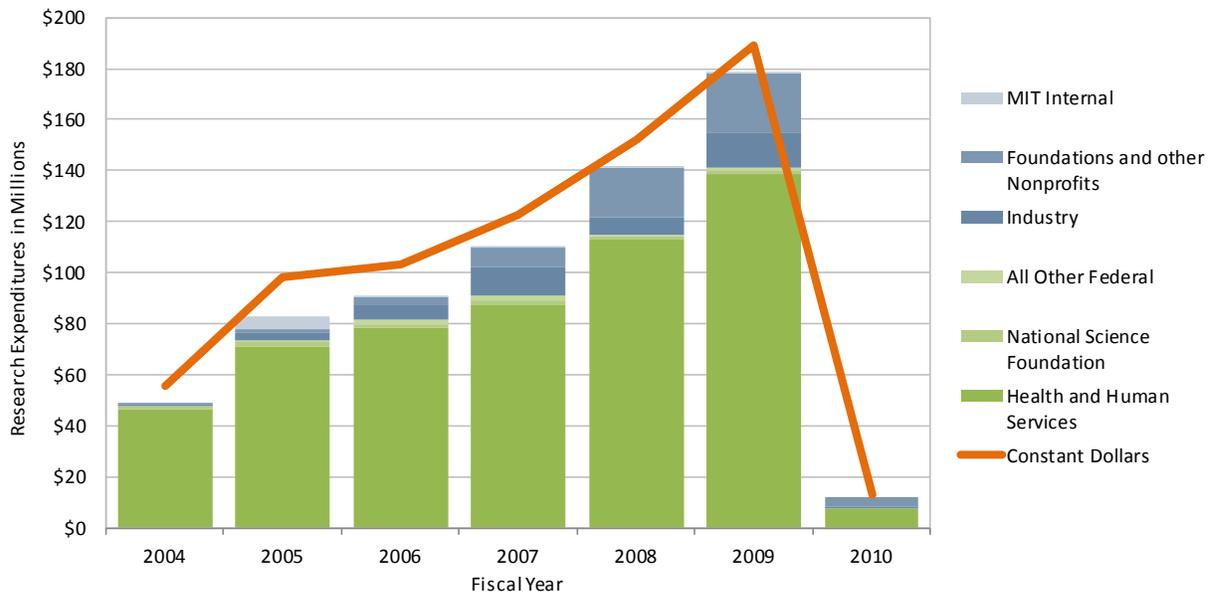
Broad scientists pursue a wide variety of projects that cut across scientific disciplines and institutions. Collectively, these projects aim to: assemble a complete picture of the molecular components of life; define the biological circuits that underlie cellular responses; uncover the molecular basis of major in-

herited diseases; unearth all the mutations that underlie different cancer types; discover the molecular basis of major infectious diseases; and transform the process of therapeutic discovery and development.

MIT administered Broad Institute research expenditures during FY2004–FY2010. The Broad Institute separated from MIT on July 1, 2009. The chart below displays Broad Institute research expenditures funded through MIT. Five MIT faculty members are currently core members of the Broad Institute. Their research expenditures are not reflected in the campus research expenditures totals found in the rest of this section.

Broad Institute Research Expenditures by Sponsor (in U.S. dollars)*
Fiscal Years 2004–2010

	2004	2005	2006	2007	2008	2009	2010
Health and Human Services	46,344,769	71,220,070	78,238,123	87,315,284	112,958,244	138,935,579	7,637,672
National Science Foundation	1,304,105	1,809,782	1,416,267	2,107,756	1,022,548	990,917	(772)
All other federal	33,683	464,691	1,912,009	1,377,190	919,377	1,113,471	79,716
Industry	514,186	3,200,233	5,944,244	11,242,651	6,935,104	13,656,981	680,132
Nonprofit organizations	425,355	1,432,595	2,694,886	7,683,458	19,370,397	23,376,207	3,792,875
MIT internal	(3,317,186)	4,516,525	143,822	549,160	341,683	74,792	0
Total	45,304,913	82,643,895	90,349,350	110,275,500	141,547,351	178,147,946	12,189,623
Constant dollars†	55,401,735	98,109,832	103,322,554	122,930,748	152,153,320	188,859,674	12,798,706



*The Broad Institute separated from MIT on July 1, 2009 and no longer receives funding through MIT.

† Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2012 equaling 100.

MIT and the American Recovery and Reinvestment Act

The 2009 economic stimulus package, the American Recovery and Reinvestment Act (ARRA), provided support for science funding at a time when universities nationwide were facing funding cutbacks and financial concerns due to the recession. Overall, ARRA provided \$22 billion in one-time research and development (R&D) funding for fiscal years 2009 (FY2009) and 2010 (FY2010), in addition to regularly appropriated funds. This funding was included in the legislation to help fulfill its purpose of “reinvestment”; since R&D support is directly related to the nation’s innovation capacity and therefore its longer term economic strength, the Congress allocated approximately two percent of the total funding in the legislation to R&D.

In most cases, ARRA R&D funding was applied toward existing research proposals that had received high ratings within agencies but had not been awarded due to funding limitations. In some cases, however, ARRA funding was applied toward new initiatives. For example at DoE, ARRA included the initial funding (\$400 million) for the new Advanced Research Projects Agency-Energy (ARPA-E) and full five-year funding for additional Energy Frontier Research Centers (EFRCs). MIT has received several ARPA-E awards to date, and houses two EFRCs, one of which is funded through ARRA.

MIT’s total ARRA expenditures through the 3rd quarter of fiscal year 2013 ending March 31, 2013 total \$138,060,960.

For the quarter January 1, 2013–March 31, 2013, MIT reported that 111.89 jobs were created or retained with ARRA funding.

The following are a selection of some of the various research projects at MIT supported by ARRA:

ARPA-E: Energy Storage for the Nation’s Energy Grid

With a nearly \$7 million five-year grant from the newly formed ARPA-E (Advanced Research Projects Agency-Energy), a group led by Donald Sadoway is developing an innovative solution to the problem of storing huge amounts of energy as part of the nation’s energy grid—a liquid metal battery. The first of its kind, the all-liquid battery is designed to use low-cost, abundant molten metals. ARPA-E predicts the liquid battery technology “could revolutionize the way electricity is used and produced on the grid, enabling round-the-clock power from America’s wind and solar power resources, increasing the stability of the grid, and making blackouts a thing of the past.”

Neutrino Physics at MIT

New findings from physicists at MIT may force scientists to rethink the Standard Model, the theory that serves as the foundation of particle physics. Scientists led by Janet Conrad at MIT’s Neutrino and Dark Matter Group have observed unexpected behavior in neutrinos, tiny particles generated by nuclear reactions in the sun. These unexpected behaviors suggest there are more types of neutrinos than the three specified in the Standard Model. To investigate these observations, the group is designing a state-of-the-art 100-ton liquid argon chamber detection device in collaboration with the Fermi National Acceleration Laboratory. The detector is scheduled to begin operating in 2013.

ARRA awards at MIT

Original source of funding	Number of awards	Obligated amount (in U.S. dollars)	Total expenditures (in U.S. dollars)
Department of Energy	27	53,867,333	43,311,690
Health and Human Services/ National Institutes of Health	91	63,252,892	62,185,134
National Science Foundation	62	30,818,602	29,379,260
NASA	3	885,212	885,212
All other agencies	7	2,644,100	2,299,664

