Section 3
Campus Research

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 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 FY2014)

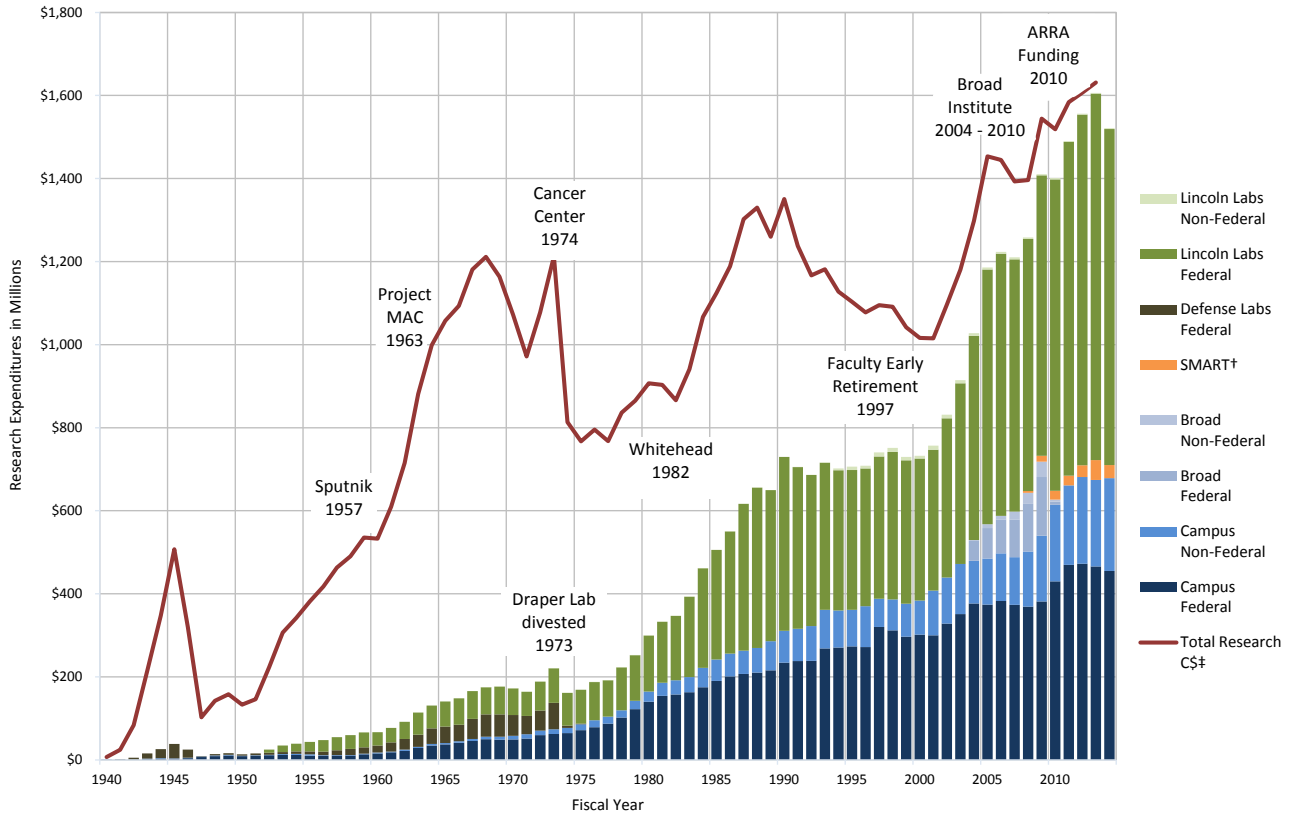
Cambridge campus	$678.4 million
Lincoln Laboratory*	$811.3 million
SMART*	$31.6 million
Total	**$1,521.3 million**

*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 FY2014, there were 2,601 active awards and 389 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 1940–2014



†SMART: Singapore-MIT Alliance for Research and Technology

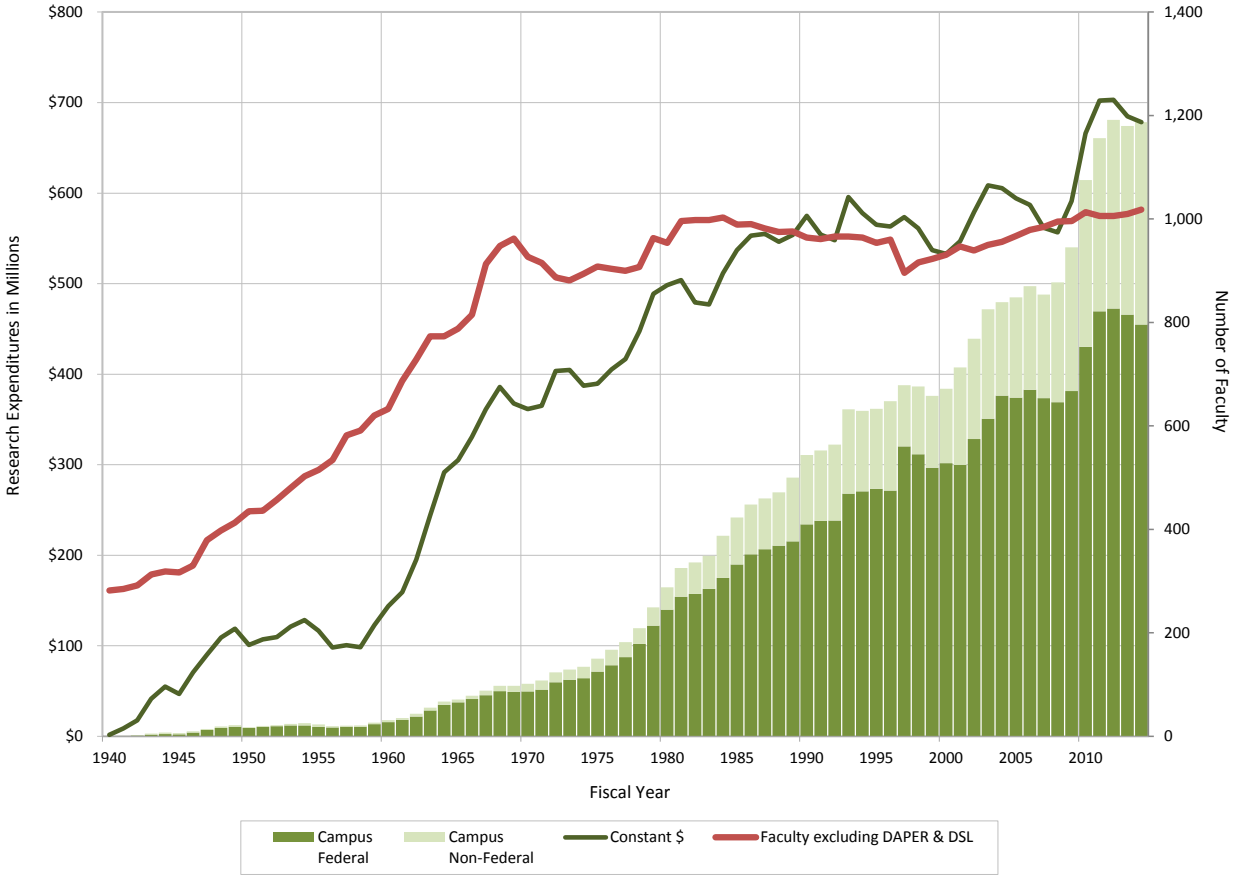
‡Total Research constant dollars are calculated using the Consumer Price Index for all Urban Consumers weighted with fiscal year 2014 equaling 100.

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 1940–2014



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

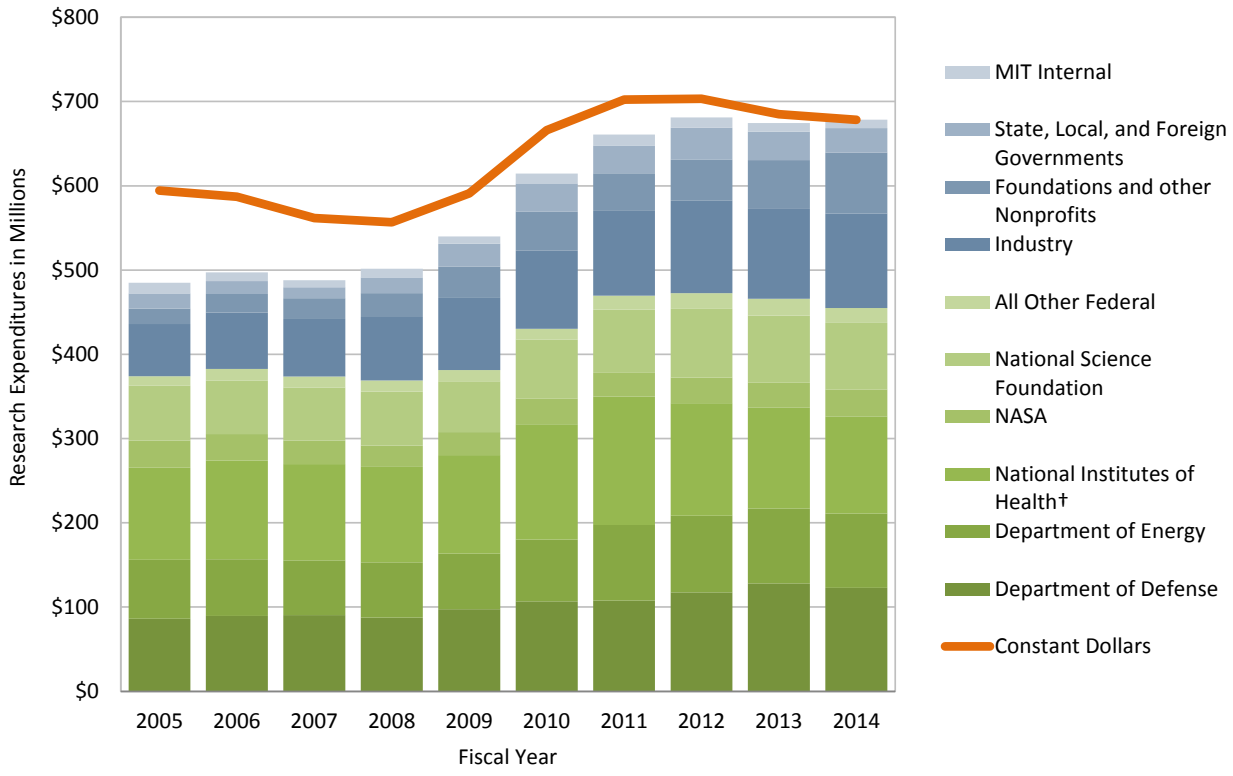
Campus Research Sponsors

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 71. Expenditures funded by industrial sponsors are shown on page 91 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 2005–2014

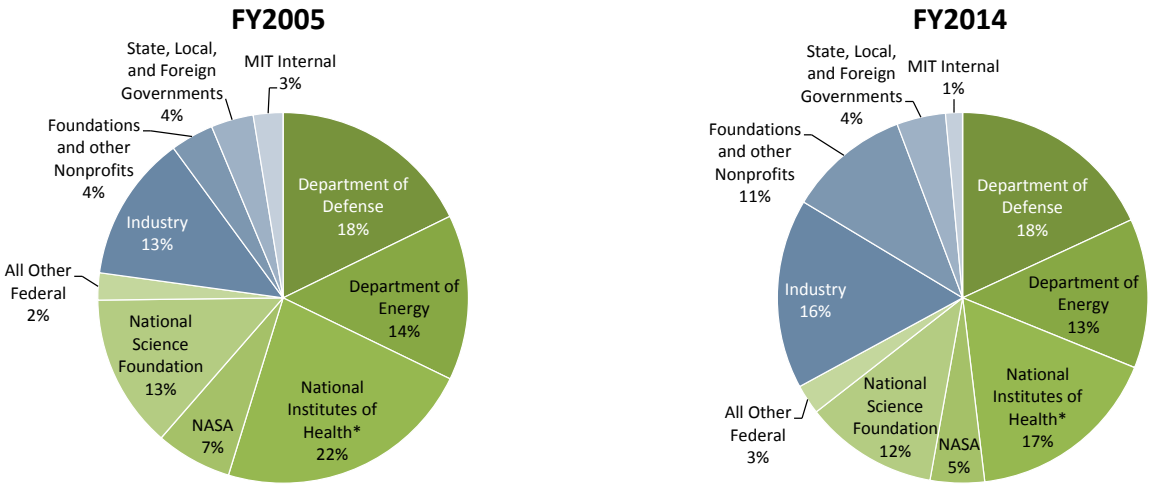
	2005	2006	2007	2008	2009
Federal	374,103,793	382,784,774	373,603,371	369,008,780	381,459,466
Non-federal	110,675,892	114,361,780	114,389,201	132,487,316	158,595,887
Total	**484,779,685**	**497,146,554**	**487,992,571**	**501,496,096**	**540,055,353**
Constant dollars*	594,218,336	587,022,048	561,687,268	556,605,026	591,148,473

	2010	2011	2012	2013	2014
Federal	430,154,479	469,520,579	472,582,743	465,946,679	454,938,599
Non-federal	184,216,417	191,304,692	208,496,567	208,401,668	223,473,071
Total	**614,370,896**	**660,825,271**	**681,079,310**	**674,348,348**	**678,411,670**
Constant dollars*	666,049,163	702,308,587	703,230,287	684,881,260	678,411,670



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2014 equaling 100.
†National Institutes of Health data includes expenditures from other Department of Health and Human Services agencies which account for less than 1% of expenditures per year.

Campus Research Expenditures by Primary Sponsor



Campus Research Expenditures by Primary Sponsor

Primary Sponsor	FY2014 (in U.S. Dollars)	Percent of Campus Total†
Department of Defense	122,761,059	18
Department of Energy	88,450,656	13
National Institutes of Health*	115,074,564	17
NASA	32,062,601	5
National Science Foundation	78,978,705	12
All other federal	17,611,014	3
Total Federal	**454,938,599**	**67**
Industry	112,379,455	17
Foundations and other nonprofits	72,117,488	11
State, local, and foreign governments	28,966,678	4
MIT internal	10,009,449	1
Total Non-Federal	**223,473,071**	**33**
Campus Total	**678,411,670**	**100**

*National Institutes of Health data includes expenditures from other Department of Health and Human Services agencies which account for less than 1% of expenditures per year.
†Percentages may not total due to rounding.

Department of Defense

Selected Projects

Magnetic brain stimulation

Researchers at MIT have developed a method to stimulate brain tissue using external magnetic fields and injected magnetic nanoparticles—a technique allowing direct stimulation of neurons, which could be an effective treatment for a variety of neurological diseases, without the need for implants or external connections.

In their study, the team injected magnetic iron oxide particles just 22 nanometers in diameter into the brain. When exposed to an external alternating magnetic field—which can penetrate deep inside biological tissues—these particles rapidly heat up. The resulting local temperature increase can then lead to neural activation by triggering heat-sensitive capsaicin receptors. The new work has proven that the approach is feasible, but much work remains to turn this proof-of-concept into a practical method for brain research or clinical treatment.

The research, conducted by Polina Anikeeva, graduate student Ritchie Chen, postdoc Gabriela Romero, graduate student Michael Christiansen, and undergraduate Alan Mohr, has been published in the journal *Science*. The work was funded by the Defense Advanced Research Projects Agency, MIT's McGovern Institute for Brain Research, and the National Science Foundation.

http://newsoffice.mit.edu/2015/magnetic-brain-stimulation-0312

A mollusk of a different stripe

The blue-rayed limpet is a tiny mollusk that lives in kelp beds along the coasts of Norway, Iceland, the United Kingdom, Portugal, and the Canary Islands. These diminutive organisms—as small as a fingernail—might escape notice entirely, if not for a very conspicuous feature: bright blue dotted lines that run in parallel along the length of their translucent shells.

Scientists at MIT and Harvard University have identified two optical structures within the limpet's shell that give its blue-striped appearance. The structures are configured to reflect blue light while absorbing all other wavelengths of incoming light. The researchers speculate that such patterning may have evolved to protect the limpet, as the blue lines resemble the color displays on the shells of more poisonous soft-bodied snails.

The findings, reported in the journal *Nature Communications*, represent the first evidence of an organism using mineralized structural components to produce optical displays. While birds, butterflies, and beetles can display brilliant blues, among other colors, they do so with organic structures, such as feathers, scales, and plates. The limpet, by contrast, produces its blue stripes through an interplay of inorganic, mineral structures, arranged in such a way as to reflect only blue light.

The researchers say such natural optical structures may serve as a design guide for engineering color-selective, controllable, transparent displays that require no internal light source and could be incorporated into windows and glasses.

The researchers included Mathias Kolle, Ling Li and Christine Ortiz at MIT and James Weaver and Joanna Aizenberg at Harvard. This research was funded in part by the Air Force Office of Scientific Research, the National Science Foundation, and the Alexander von Humboldt Foundation.

http://newsoffice.mit.edu/2015/optical-structures-in-limpet-shell-0226

Detecting gases wirelessly and cheaply

MIT chemists have devised a new way to wirelessly detect hazardous gases and environmental pollutants, using a simple sensor that can be read by a smartphone.These inexpensive sensors could be widely deployed, making it easier to monitor public spaces or detect food spoilage in warehouses. Using this system, the researchers have demonstrated that they can detect gaseous ammonia, hydrogen peroxide, and cyclohexanone, among other gases.

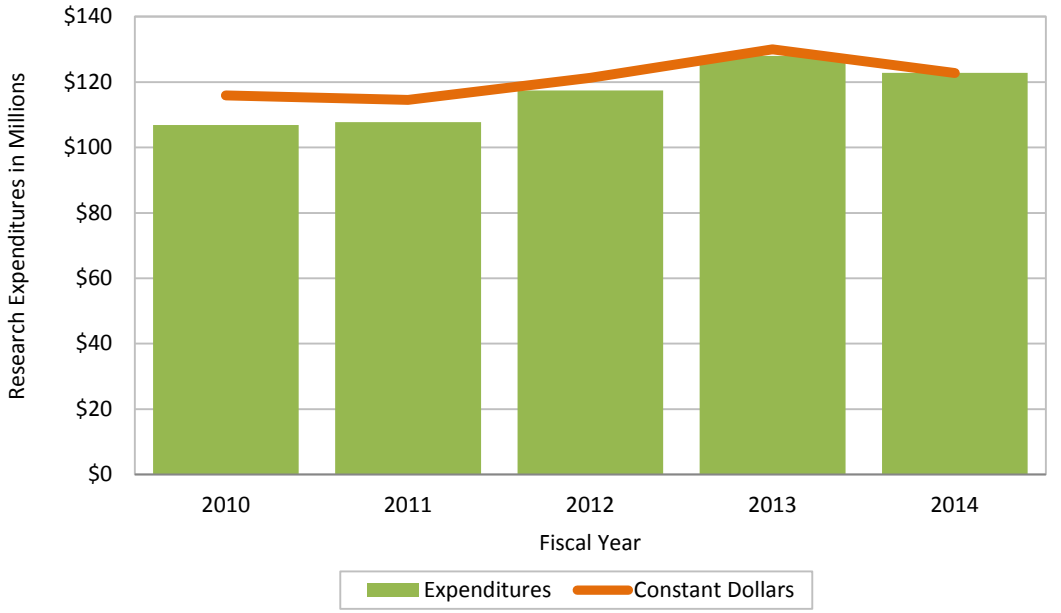
Timothy Swager is the senior author of a paper describing the new sensors in the P*roceedings of the National Academy of Sciences*. Graduate student Joseph Azzarelli is the paper's lead author; other authors are postdoc Katherine Mirica and former postdoc Jens Ravnsbaek.

The research was funded by the U.S. Army Research Laboratory and the U.S. Army Research Office through the MIT Institute for Soldier Nanotechnologies; the MIT Deshpande Center for Technological Innovation; and the National Cancer Institute.

http://newsoffice.mit.edu/2014/wireless-chemical-sensor-for-smartphone-1208

Department of Defense Campus Research Expenditures (in U.S. Dollars)
Fiscal Years 2010–2014

	2010	2011	2012	2013	2014
Campus research	106,890,338	107,753,196	117,457,789	127,966,747	122,761,059
Constant dollars*	115,881,499	114,517,405	121,277,909	129,965,510	122,761,059



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2014 equaling 100.

Leading Departments, Laboratories, and Centers Receiving Support in Fiscal Year 2014
(shown in descending order of expenditures)

Research Laboratory of Electronics
Computer Science and Artificial Intelligence Laboratory
Biological Engineering
Institute for Soldier Nanotechnologies
Mechanical Engineering
Sociotechnical Systems Research Center
Microsystems Technology Laboratories
Lab for Information & Decision Systems
Aeronautics and Astronautics
Media Laboratory

In fall 2014, the Department of Defense funded the primary appointments of graduate students with 291 research assistantships and 89 fellowships.

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

Department of Energy

Selected Projects

Engineering earth-abundant catalysts that mimic platinum in renewable energy technologies

When one considers nonrenewable resources, the first to come to mind are fossil fuels. The rapid depletion of these unsustainable resources has sparked global research on renewable-energy technologies, such as fuel cells, electrolyzers, and lithium-air batteries.

Unfortunately there is a common unsustainable thread that links these burgeoning technologies: a dependence on platinum-group metals (PGMs). These elements—platinum, palladium, rhodium, iridium, ruthenium, and osmium—are the six least-abundant in the Earth's lithosphere, yet are the most stable and active catalysts. Even with efficient recycling, numerous studies have indicated that the Earth simply does not contain enough PGMs to support a global renewable-energy economy. Thus, PGMs can be considered unsustainable resources that are currently needed to enable renewable energy technologies.

Graduate student Sean Hunt, postdoc Tarit Nimmandwudipong, and Yuriy Román, have an idea for how to replace PGMs with metals that are more plentiful. In a paper published in the journal *Angewandte Chemie*, the team explained its process of synthesizing these alternative catalysts. In the simplest sense, one can imagine that tungsten can be electronically modified to mimic platinum by reacting it with carbon to give the ceramic material tungsten carbide (WC). Studies have shown that WC is indeed platinumlike, and able to catalyze important thermo- and electrocatalytic reactions that tungsten metal cannot. Importantly, tungsten is more than three orders of magnitude more abundant than platinum in the Earth's crust, making it a viable material for a global renewable-energy economy.

http://newsoffice.mit.edu/2014/engineering-earth-abundant-catalysts-mimic-platinum-renewable-energy-technologies

Unconventional photoconduction in an atomically thin semiconductor

It's a well-known phenomenon in electronics: Shining light on a semiconductor, such as the silicon used in computer chips and solar cells, will make it more conductive. But now researchers have discovered that in a special semiconductor, light can have the opposite effect, making the material less conductive instead.

The phenomenon was discovered in an exotic two-dimensional semiconductor—a single layer of molybdenum disulfide (MoS_2) just three atoms thick. The finding is reported in a paper in *Physical Review Letters* by postdoc Joshua Lui; Nuh Gedik; and six others at MIT, Harvard University, and in Taiwan.

When a semiconductor is illuminated by light, its conductivity tends to increase. The MIT team, however, observed the opposite behavior in a two-dimensional semiconductor. The researchers found that when illuminated by intense laser pulses, single-layer MoS_2 is reduced to approximately one-third of its initial conductivity.

Lui says "One remarkable property of these materials is the strong confinement of charge carriers in a two-dimensional plane. … As a consequence, the electrostatic interactions between the charge carriers are much stronger than those in three-dimensional solids."

The strong electrostatic interactions give rise to an interesting effect: When light generates an electron-hole pair in the material, instead of flying off freely as they would in a three-dimensional solid, they remain bound together. Such a bound state is called an exciton.

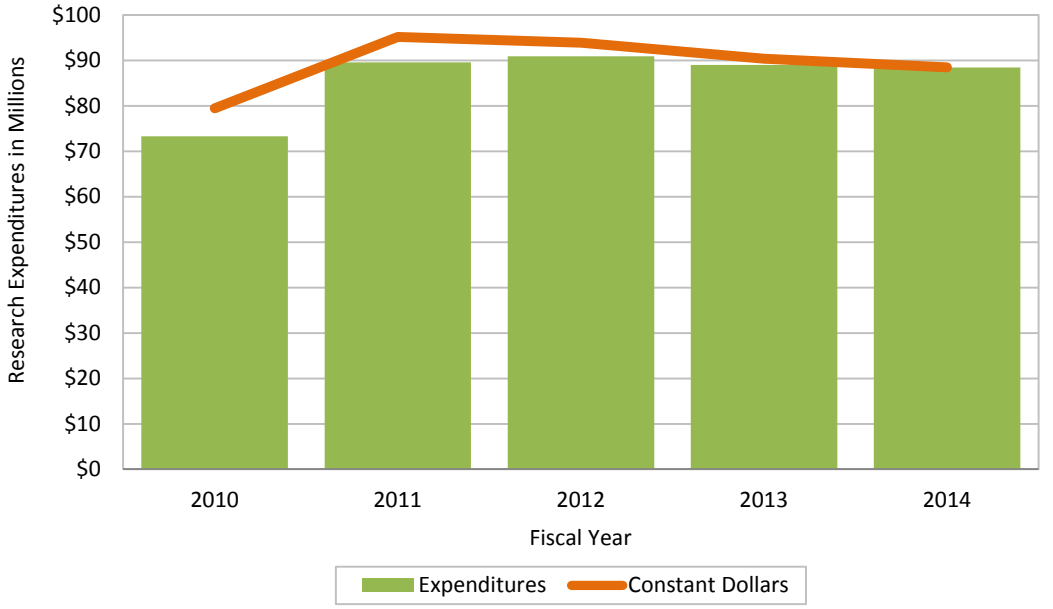
Gedik says that the work "might help us to realize room-temperature excitonic devices," which would otherwise require extremely low temperatures. In addition, because the effect can be switched on and off using light pulses, such devices could be easy to control without wired connections.

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

http://newsoffice.mit.edu/2014/light-makes-semiconductor-less-conductive-1007

Department of Energy Campus Research Expenditures (in U.S. Dollars)
Fiscal Years 2010–2014

	2010	2011	2012	2013	2014
Campus research	73,273,733	89,562,126	90,940,035	88,987,983	88,450,656
Constant dollars*	79,437,208	95,184,389	93,897,709	90,377,922	88,450,656



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2014 equaling 100.

Leading Departments, Laboratories, and Centers Receiving Support in Fiscal Year 2014
(shown in descending order of expenditures)

Plasma Science and Fusion Center
Laboratory for Nuclear Science
Materials Processing Center
Research Laboratory of Electronics
Mechanical Engineering
Chemical Engineering
Nuclear Science and Engineering
Nuclear Reactor Laboratory
Materials Science and Engineering
Computer Science and Artificial Intelligence Laboratory

In fall 2014, the Department of Energy funded the primary appointments of graduate students with 191 research assistantships and 22 fellowships.

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

National Institutes of Health

Selected Projects

Quick test for Ebola

When diagnosing a case of Ebola, time is of the essence. However, existing diagnostic tests take at least a day or two to yield results, preventing health care workers from quickly determining whether a patient needs immediate treatment and isolation.

A new test from MIT researchers could change that: The device, a simple paper strip similar to a pregnancy test, can rapidly diagnose Ebola, as well as other viral hemorrhagic fevers such as yellow fever and dengue fever.

The new device relies on lateral flow technology, which is used in pregnancy tests and has recently been exploited for diagnosing strep throat and other bacterial infections. Unlike most existing paper diagnostics, which test for only one disease, the new MIT strips are color-coded so they can be used to distinguish among several diseases. To achieve that, the researchers used triangular nanoparticles, made of silver, that can take on different colors depending on their size. This type of device could also be customized to detect other viral hemorrhagic fevers or other infectious diseases, by linking the silver nanoparticles to different antibodies.

Kimberly Hamad-Schifferli and Lee Gehrke are the senior authors of a paper describing the new device in the journal *Lab on a Chip*. The paper's lead author is postdoc Chun-Wan Yen, and other authors are graduate student Helena de Puig, postdoc Justina Tam, instructor Jose Gomez-Marquez, and visiting scientist Irene Bosch. The research was funded by the National Institute of Allergy and Infectious Disease.

http://newsoffice.mit.edu/2015/ten-minute-ebola-test-0224

MIT researchers design tailored tissue adhesives

After undergoing surgery to remove diseased sections of the colon, up to 30 percent of patients experience leakage from their sutures, which can cause life-threatening complications. Many efforts are under way to create new tissue glues that can help seal surgical incisions and prevent such complications; now, a new study from MIT reveals that the effectiveness of such glues hinges on the state of the tissue in which they are being used.

The researchers found that a sealant they had previously developed worked much differently in cancerous colon tissue than in colon tissue inflamed with colitis. The finding suggests that for this sealant or any other kind of biomaterial designed to work inside the human body, scientists must take into account the environment in which the material will be used, instead of using a "one-size fits all" approach, according to the researchers.

The tissue glue works through a system where molecules in the adhesive serve as "keys" that interact with "locks"—chemical structures called amines found in abundance in structural tissue known as collagen. When enough of these locks and keys bind to each other, the adhesive forms a tight seal. This system is disrupted in colitic tissue because the inflammation breaks down collagen. The more severe the inflammation, the less adhesion occurs. However, cancerous tissue tends to have excess collagen, so the adhesive ends up working better than in healthy tissue.

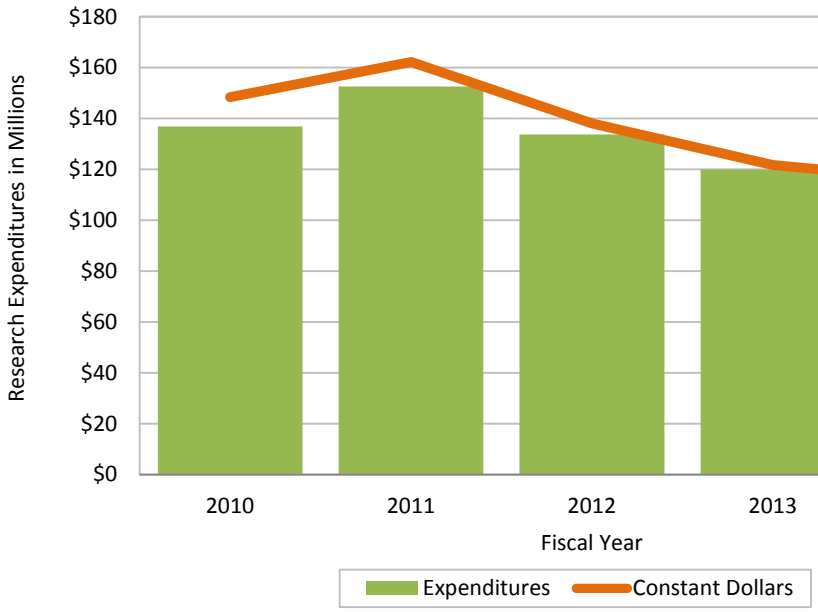
Using this data, the researchers created a model to help them alter the composition of the material depending on the circumstances. By changing the materials' molecular weight, the researchers can tune it to perform best in different types and states of tissue.

Natalie Artzi and Elazer Edelman are senior author of a paper describing the findings in *Science Translational Medicine*. The paper's lead authors are graduate student Nuria Oliva and former graduate student Maria Carcole. The research was funded by the National Institutes of Health and the MIT Deshpande Center for Technological Innovation.

http://newsoffice.mit.edu/2015/tailored-tissue-adhesives-0128

National Institutes of Health Campus Research Expenditures (in U.S. Dollars)*
Fiscal Years 2010–2014

	2010	2011	2012	2013	2014
Campus research	136,923,238	152,664,013	133,687,332	119,908,451	115,074,564
Constant dollars†	148,440,638	162,247,499	138,035,291	121,781,348	115,074,564



*National Institutes of Health data includes expenditures from other Department of Health and Human Services agencies which account for less than 1% of expenditures per year.
†Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2014 equaling 100.

Leading Departments, Laboratories, and Centers Receiving Support in Fiscal Year 2014
(shown in descending order of expenditures)

Koch Institute for Integrative Cancer Research
Biology
Biological Engineering
Chemistry
Picower Institute for Learning and Memory
McGovern Institute for Brain Research
Plasma Science and Fusion Center
Center for Environmental Health Sciences
Research Laboratory of Electronics
Institute for Medical Engineering and Science

In fall 2014, the National Institutes of Health and other Department of Health and Human Services programs funded the primary appointments of graduate students with 167 research assistantships and 32 fellowships.

Eleven current faculty or staff have received the NIH Director's Pioneer Award. The recipients are Edward Boyden, Emery Brown, Arup Chakraborty, James Collins, Hidde Ploegh, Aviv Regev, Leona Samson, Alice Ting, Alexander van Oudenaarden, Mehmet Yanik, and Feng Zhang.

NASA

Selected Projects

A second minor planet may possess Saturn-like rings

There are only five bodies in our solar system that are known to bear rings. The planet Saturn; to a lesser extent, rings of gas and dust also encircle Jupiter, Uranus, and Neptune. The fifth member of this haloed group is Chariklo, one of a class of minor planets called centaurs: small, rocky bodies that possess qualities of both asteroids and comets.

Scientists only recently detected Chariklo's ring system—a surprising finding, as it had been thought that centaurs are relatively dormant. Scientists at MIT and elsewhere have detected a possible ring system around a second centaur, Chiron.

The group observed a stellar occultation in which Chiron passed in front of a bright star. The researchers analyzed the star's light emissions, and the momentary shadow created by Chiron, and identified optical features that suggest the centaur may possess a circulating disk of debris. The team believes the features may signify a ring system.

Amanda Bosh, Jessica Ruprecht, Michael Person, and Amanda Gulbis have published their results in the journal *Icarus*. This research was funded in part by NASA and the National Research Foundation of South Africa.

http://newsoffice.mit.edu/2015/planet-chiron-saturn-like-rings-0317

A twist on planetary origins

Meteors that have crashed to Earth have long been regarded as relics of the early solar system. These craggy chunks of metal and rock are studded with chondrules—tiny, glassy, spherical grains that were once molten droplets. Scientists have thought that chondrules represent early kernels of terrestrial planets: As the solar system started to coalesce, these molten droplets collided with bits of gas and dust to form larger planetary precursors.

Researchers at MIT and Purdue University have found that chondrules may have played less of a fundamental role. Based on computer simulations, the group concludes that chondrules were not building blocks, but rather byproducts of a violent and messy planetary process. Postdoc Brandon Johnson says the findings revise one of the earliest chapters of the solar system. Johnson and his colleagues, including Maria Zuber, have published their results in the journal *Nature*.

http://newsoffice.mit.edu/2015/meteorites-byproducts-of-planetary-formation-0114

Plasma shield

High above Earth's atmosphere, electrons whiz past at close to the speed of light. Such ultrarelativistic electrons, which make up the outer band of the Van Allen radiation belt, streak around the planet bombarding anything in their path. Exposure to such high-energy radiation can wreak havoc on satellite electronics, and pose serious health risks to astronauts.

Researchers at MIT, the University of Colorado, and elsewhere have found there's a hard limit to how close ultrarelativistic electrons can get to the Earth. The team found that no matter where these electrons are circling around the planet's equator, they can get no further than about 11,000 kilometers from the Earth's surface—despite their intense energy.

What's keeping this high-energy radiation at bay seems to be a phenomenon termed "plasmaspheric hiss"—very low-frequency electromagnetic waves in the Earth's upper atmosphere. The researchers believe that plasmaspheric hiss essentially deflects incoming electrons, causing them to collide with neutral gas atoms in the Earth's upper atmosphere, and ultimately disappear.

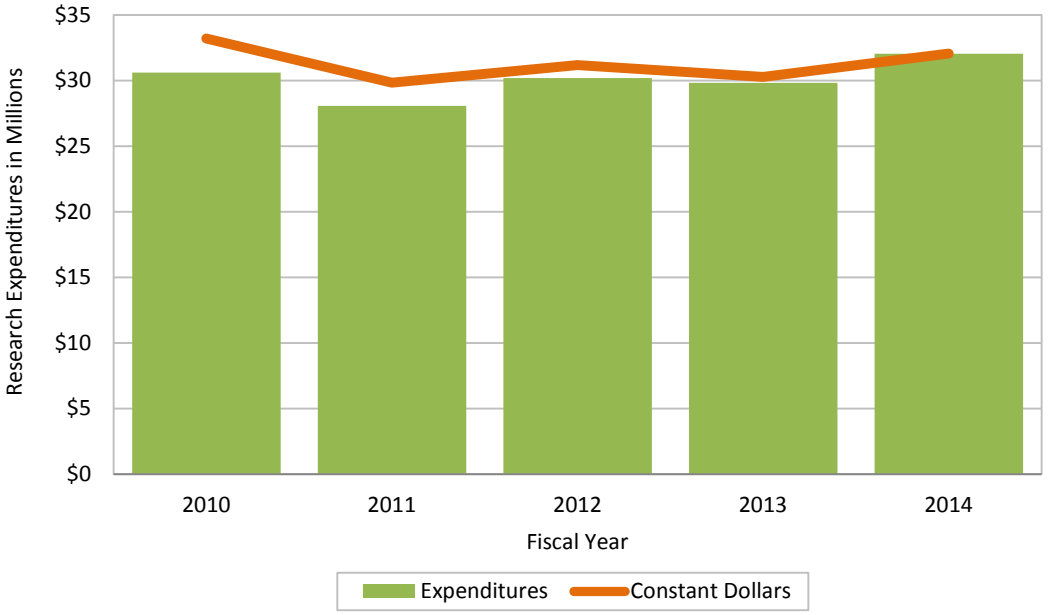
"It's a very unusual, extraordinary, and pronounced phenomenon," says John Foster, associate director of MIT's Haystack Observatory. "What this tells us is if you parked a satellite or an orbiting space station with humans just inside this impenetrable barrier, you would expect them to have much longer lifetimes. That's a good thing to know."

Foster and his colleagues, including lead author Daniel Baker of the University of Colorado, have published their results in the journal *Nature*. This research was funded in part by NASA.

http://newsoffice.mit.edu/2014/plasma-shield-against-harmful-radiation-1126

NASA Campus Research Expenditures (in U.S. Dollars)
Fiscal Years 2010–2014

	2010	2011	2012	2013	2014
Campus research	30,629,006	28,079,693	30,203,575	29,834,713	32,062,601
Constant dollars*	33,205,388	29,842,396	31,185,897	30,300,713	32,062,601



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2014 equaling 100.

Leading Departments, Laboratories, and Centers Receiving Support in Fiscal Year 2014
(shown in descending order of expenditures)

Kavli Institute for Astrophysics and Space Research
Earth, Atmospheric, and Planetary Sciences
Aeronautics and Astronautics
Haystack Observatory
Earth System Initiative
Center for Global Change Science
Research Laboratory of Electronics
Media Laboratory
Computer Science and Artificial Intelligence Laboratory
Mechanical Engineering

In fall 2014, NASA funded the primary appointments of graduate students with 53 research assistantships and 24 fellowships.

National Science Foundation

Selected Projects

New detector sniffs out origins of methane

Methane is a potent greenhouse gas, second only to carbon dioxide in its capacity to trap heat in Earth's atmosphere for a long time. The gas can originate from lakes and swamps, natural-gas pipelines, deep-sea vents, and livestock. Understanding the sources of methane, and how the gas is formed, could give scientists a better understanding of its role in warming the planet.

A research team led by scientists at MIT and including colleagues from the Woods Hole Oceanographic Institution, the University of Toronto, and elsewhere has developed an instrument that can rapidly and precisely analyze samples of environmental methane to determine how the gas was formed.

The approach, called tunable infrared laser direct absorption spectroscopy, detects the ratio of methane isotopes, which can provide a "fingerprint" to differentiate between two common origins: microbial, in which microorganisms, typically living in wetlands or the guts of animals, produce methane as a metabolic byproduct; or thermogenic, in which organic matter, buried deep within the Earth, decays to methane at high temperatures.

Shuhei Ono and his colleagues, including first author and graduate student David Wang, publish their results in the journal *Science*. This research was funded in part by the National Science Foundation, Shell Oil, the Deep Carbon Observatory, the National Sciences and Engineering Research Council of Canada, and the German Research Foundation.

http://newsoffice.mit.edu/2015/detector-sniffs-out-methane-0305

Underwater robot for port security

In 2014, MIT researchers unveiled an oval-shaped submersible robot, a little smaller than a football, with a flattened panel on one side that it can slide along an underwater surface to perform ultrasound scans. Originally designed to look for cracks in nuclear reactors' water tanks, the robot could also inspect ships for the false hulls and propeller shafts that smugglers frequently use to hide contraband. Because of its small size and unique propulsion mechanism—which leaves no visible wake—the robots could, in theory, be concealed in clumps of algae or other camouflage. Fleets of them could swarm over ships at port without alerting smugglers and giving them the chance to jettison their cargo.

Graduate student Sampriti Bhattacharyya designed the robot together with her advisor, Harry Asada. The MIT research was funded by the National Science Foundation.

http://newsoffice.mit.edu/2014/underwater-robot-for-port-security-0926

Morphable surfaces could cut air resistance

There is a story about how the modern golf ball came to be: In the mid-1800s, it is said, new golf balls were smooth, but became dimpled over time as impacts left permanent dents. Smooth new balls were typically used for tournament play, but in one match, a player ran short, had to use an old, dented one, and realized that he could drive this dimpled ball much further than a smooth one. Whether that story is true or not, testing over the years has proved that a golf ball's irregular surface really does dramatically increase the distance it travels, because it can cut the drag caused by air resistance in half. Researchers at MIT are aiming to harness that same effect to reduce drag on a variety of surfaces—including domes that sometimes crumple in high winds, or perhaps even vehicles.

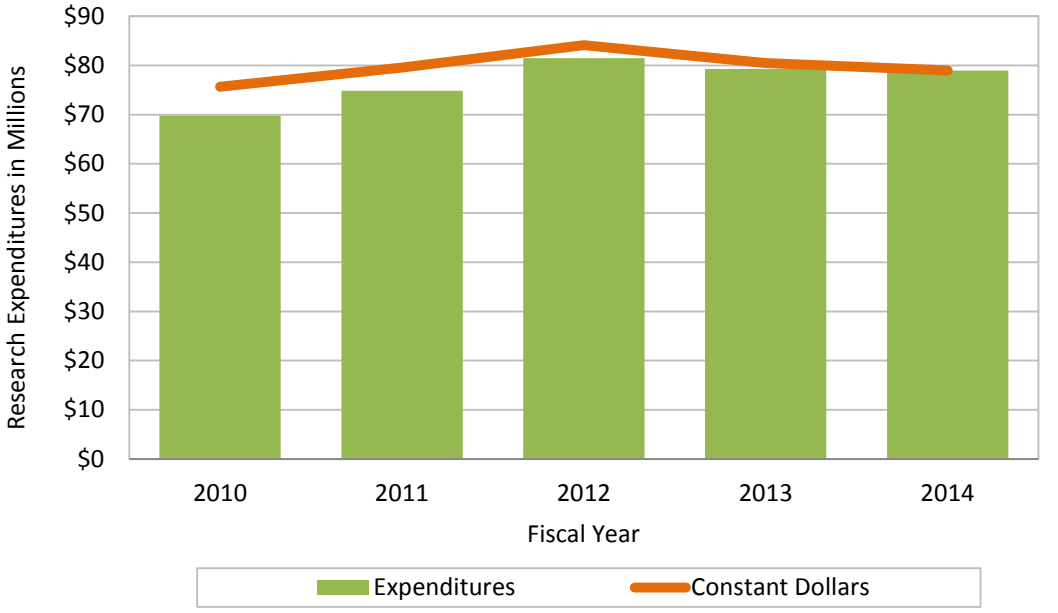
Detailed studies have shown that while a ball with a dimpled surface has half the drag of a smooth one at lower speeds, at higher speeds that advantage reverses. So the ideal would be a surface whose smoothness can be altered, literally, on the fly—and that's what the MIT team has developed.

The work is described in a paper in the journal *Advanced Materials* by Pedro Reis and former post-docs Denis Terwagne and Miha Brojan. The research was supported by the National Science Foundation, MIT's Charles E. Reed Faculty Initiatives Fund, the Wallonie-Bruxelles International, the Belgian American Education Foundation, and the Fulbright Foundation.

http://newsoffice.mit.edu/2014/morphable-surfaces-could-cut-air-resistance-0624

National Science Foundation Campus Research Expenditures (in U.S. Dollars)
Fiscal Years 2010–2014

	2010	2011	2012	2013	2014
Campus research	69,801,369	74,859,339	81,487,208	79,255,278	78,978,705
Constant dollars*	75,672,764	79,558,635	84,137,445	80,493,197	78,978,705



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2014 equaling 100.

Leading Departments, Laboratories, and Centers Receiving Support in Fiscal Year 2014
(shown in descending order of expenditures)

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

In fall 2014, the National Science Foundation funded the primary appointments of graduate students with 287 research assistantships and 199 fellowships.

The National Science Foundation has awarded Faculty Early Career Development (CAREER) Awards to 158 current faculty and staff members.

Other Federal Agencies

Selected Projects

The missing piece of the climate puzzle

In classrooms and everyday conversation, explanations of global warming hinge on the greenhouse gas effect. In short, climate depends on the balance between two different kinds of radiation: The Earth absorbs incoming visible light from the sun, called "shortwave radiation," and emits infrared light, or "longwave radiation," into space.

Upsetting that energy balance are rising levels of greenhouse gases, such as carbon dioxide (CO_2), that increasingly absorb some of the outgoing longwave radiation and trap it in the atmosphere. Energy accumulates in the climate system, and warming occurs. In a paper in the *Proceedings of the National Academy of Sciences*, MIT researchers show that this view of global warming is only half the story.

In computer modeling of Earth's climate under elevating CO_2 concentrations, the greenhouse gas effect does indeed lead to global warming. While one would expect the longwave radiation that escapes into space to decline with increasing CO_2, the amount actually begins to rise.

"The finding was a curiosity, conflicting with the basic understanding of global warming," says lead author Aaron Donohoe, a former MIT postdoc who is now a research associate at the University of Washington's Applied Physics Laboratory. Donohoe, along with MIT postdoc Kyle Armour and others at Washington found the answer by drawing on both computer simulations and an energy-balance model. As longwave radiation gets trapped by CO_2, the Earth starts to warm. Sea ice and snow cover melt, turning brilliant white reflectors of sunlight into darker spots. The atmosphere grows moister because warmer air can hold more water vapor, which absorbs more shortwave radiation and the planet warms rapidly at the surface.

Meanwhile, Earth sheds longwave radiation more effectively, canceling out the longwave-trapping effects of CO_2. However, a darker Earth now absorbs more sunlight, tipping the scales to net warming from shortwave radiation.

The paper is not challenging the physics of climate models; its value lies in helping the community interpret their output. One way the study can be useful is in guiding what researchers look for in satellite observations of Earth's radiation budget, as they track anthropogenic climate change in the decades to come.

The work was supported by the National Oceanographic and Atmospheric Adminstration, the James S. McDonnell Foundation, and the National Science Foundation.

http://newsoffice.mit.edu/2014/global-warming-increased-solar-radiation-1110

More efficient ways to power our flights

Industry-wide, air carriers set a goal to be carbon neutral by 2020 and to cut their emissions in half by 2050. One way they'll meet this goal is through the use of biofuels.

"Biofuels release significantly fewer emissions than conventional fuel, and could reduce fuel price volatility for airlines," says Niven Winchester, the lead author of a study looking at the costs and efficiency of making the switch.

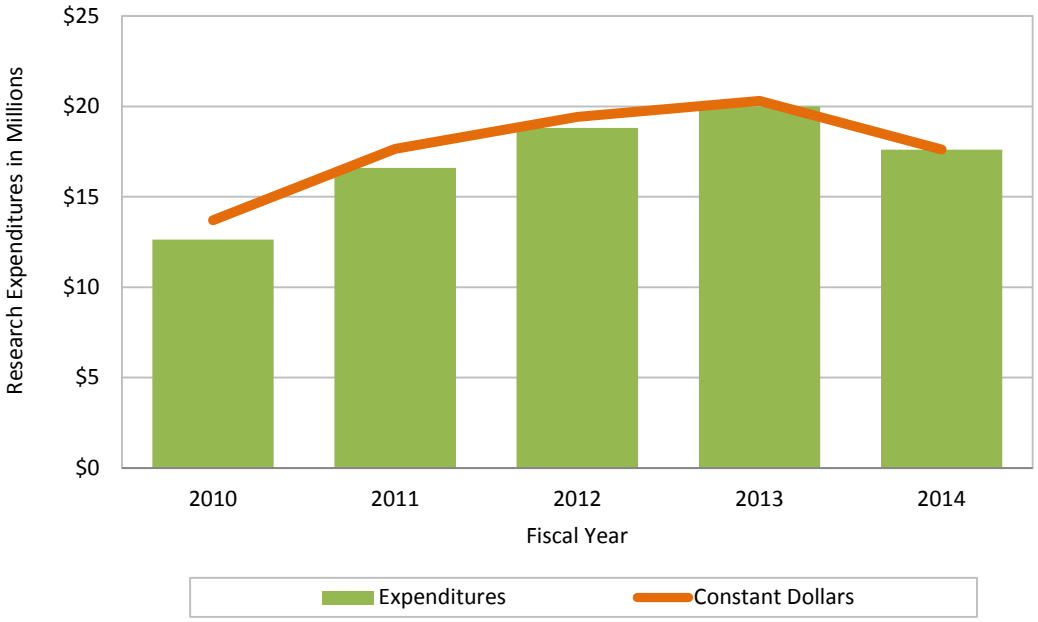
To meet the global targets, the U.S. Federal Aviation Administration (FAA) has set its own goal to use one billion gallons of renewable biofuels each year starting in 2018. In studying this target, Winchester and his co-authors find that while a carbon tax or cap-and-trade system—as the Europeans have employed—would be the most efficient way to reduce emissions, there are ways to cut the costs of using biofuels. The study was published in *Transportation Research*. The researchers found that growing biofuel crops in rotation with food crops, as research from the U.S. Department of Agriculture suggests, can reduce the cost of biofuels.

The study was funded by the FAA.

http://newsoffice.mit.edu/2013/more-efficient-ways-to-power-our-flights-1202

Other Federal Agencies Campus Research Expenditures (in U.S. Dollars)
Fiscal Years 2010–2014

	2010	2011	2012	2013	2014
Campus research	12,636,795	16,602,212	18,806,804	19,993,508	17,611,014
Constant dollars*	13,699,748	17,644,416	19,418,464	20,305,794	17,611,014



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2014 equaling 100.

A few of the leading other federal agencies providing funding are: the Department of Commerce, the Department of Transportation, the Federal Aviation Administration, the Intelligence Advanced Research Projects Activity, and the Environmental Protection Agency.

Leading Departments, Laboratories, and Centers Receiving Support in Fiscal Year 2014
(shown in descending order of expenditures)

Computer Science and Artificial Intelligence Laboratory
Center for Transportation and Logistics
Aeronautics and Astronautics
Sea Grant College Program
Mechanical Engineering
Urban Studies and Planning
Earth System Initiative
Center for Global Change Science
Media Laboratory
Research Laboratory of Electronics

In fall 2014, Other Federal Agencies funded the primary appointments of graduate students with 50 research assistantships and 1 fellowship.

Nonprofit Organizations
Selected Projects

New nanogel for drug delivery
Scientists are interested in using gels to deliver drugs because they can be molded into specific shapes and designed to release their payload over a specified time period. However, current versions aren't always practical because must be implanted surgically.

To help overcome that obstacle, MIT chemical engineers have designed a new type of self-healing hydrogel that could be injected through a syringe. Such gels, which can carry one or two drugs at a time, could be useful for treating cancer, macular degeneration, or heart disease, among other diseases, the researchers say. The new gel consists of a mesh network made of two components. Using two components to form the gel also gives the researchers the opportunity to deliver two different drugs at the same time.

Postdocs Mark Tibbitt and Eric Appel are lead authors of a paper describing the gel in *Nature Communications*. The paper's senior author is Robert Langer. Other authors are postdoc Matthew Webber, undergraduate Bradley Mattix, and postdoc Omid Veiseh.

The research was funded by the Wellcome Trust, the Misrock Foundation, the Department of Defense, and the National Institutes of Health.

http://newsoffice.mit.edu/2015/self-healing-nanogel-drug-delivery-0219

Engineered insulin could offer better diabetes control
For patients with diabetes, insulin is critical to maintaining good health and normal blood-sugar levels. However, it's not an ideal solution because it can be difficult for patients to determine exactly how much insulin they need to prevent their blood sugar from swinging too high or too low.

MIT engineers hope to improve treatment for diabetes patients with a new type of engineered insulin. In tests in mice, the researchers showed that their modified insulin can circulate in the bloodstream for at least 10 hours, and that it responds rapidly to changes in blood-sugar levels. This could eliminate the need for patients to repeatedly monitor their blood sugar levels and inject insulin throughout the day.

Daniel Anderson and Robert Langer are the senior authors of a paper describing the engineered insulin in *Proceedings of the National Academy of Sciences*. The paper's lead authors are Hung-Chieh (Danny) Chou, former postdoc Matthew Webber, and postdoc Benjamin Tang. Other authors are technical assistants Amy Lin and Lavanya Thapa, David Deng, Jonathan Truong, and Abel Cortinas.

The research was funded by the Leona M. and Harry B. Helmsley Charitable Trust, the Tayebati Family Foundation, the National Institutes of Health, and the Juvenile Diabetes Research Foundation.

http://newsoffice.mit.edu/2015/modified-insulin-better-diabetes-control-0209

New way to turn genes on
Using a gene-editing system originally developed to delete specific genes, MIT researchers have now shown that they can reliably turn on any gene of their choosing in living cells.

This new application for the CRISPR/Cas9 gene-editing system should allow scientists to more easily determine the function of individual genes, according to Feng Zhang. This approach also enables rapid functional screens of the entire genome, allowing scientists to identify genes involved in particular diseases. In a study published in *Nature*, Zhang and colleagues identified several genes that help melanoma cells become resistant to a cancer drug.

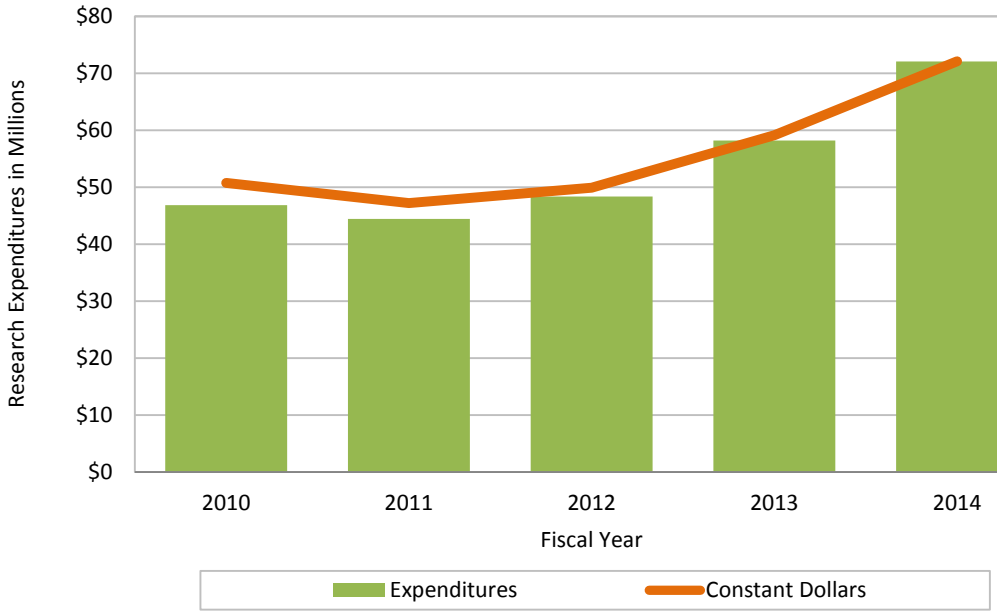
Silvana Konermann, a graduate student in Zhang's lab, and postdoc Mark Brigham are the paper's lead authors.

The research was funded by the National Institute of Mental Health; the National Institute of Neurological Disorders and Stroke; the Keck, Searle Scholars, Klingenstein, Vallee, and Simons foundations; and Bob Metcalfe.

http://newsoffice.mit.edu/2014/crispr-technique-determines-gene-function-1210

Nonprofit Organizations Campus Research Expenditures (in U.S. Dollars)
Fiscal Years 2010–2014

	2010	2011	2012	2013	2014
Campus research	46,846,106	44,436,470	48,373,460	58,226,616	72,117,488
Constant dollars*	50,786,601	47,225,970	49,946,727	59,136,081	72,117,488



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2014 equaling 100.

Leading Departments, Laboratories, and Centers
Receiving Support in Fiscal Year 2014
(shown in descending order of expenditures)

Computer Science and Artificial
Intelligence Laboratory
Mechanical Engineering
Masdar
Economics
Koch Institute for Integrative Cancer Research
Research Laboratory of Electronics
Simons Center For The Social Brain
Civil and Environmental Engineering
McGovern Institute for Brain Research
MIT-SUTD Collaboration