Section 4
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 FY2019)

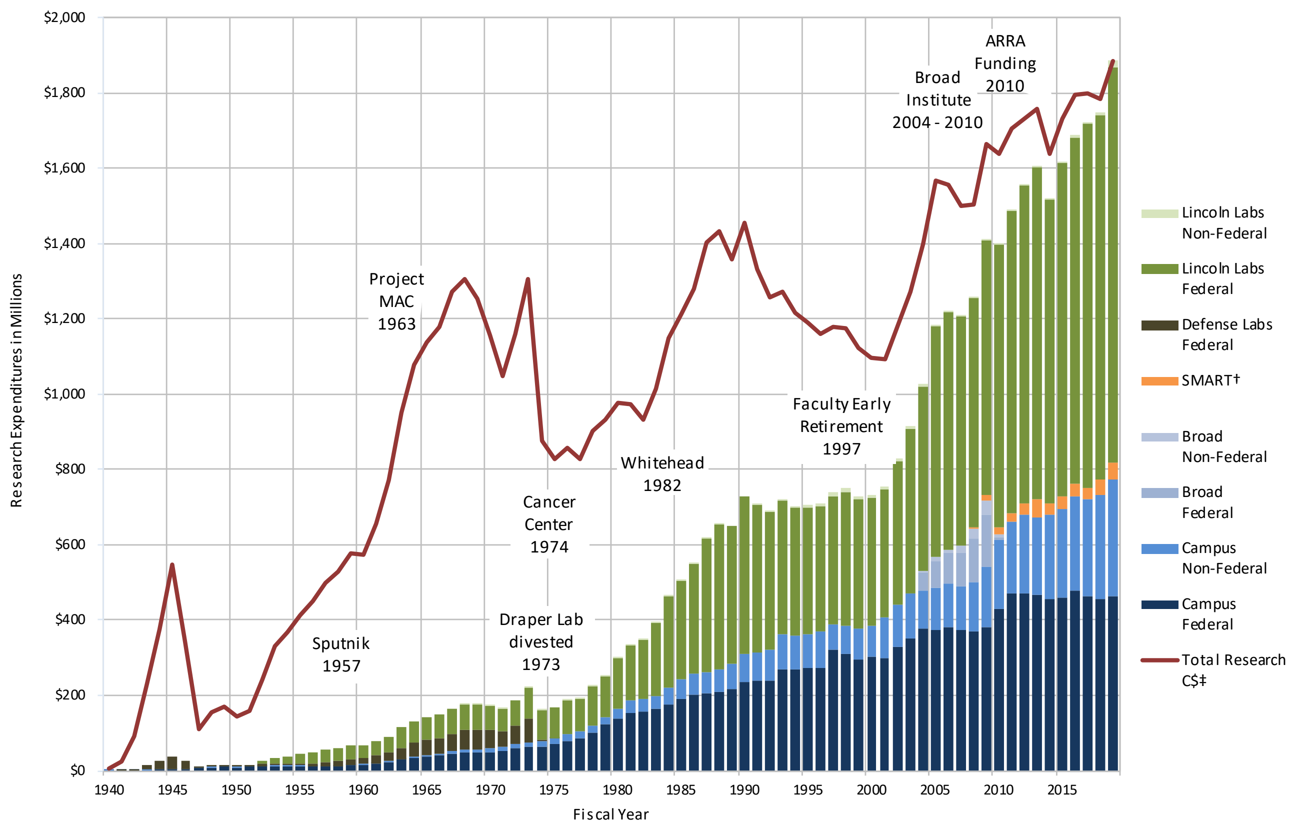
Cambridge Campus	$773.9 million
Lincoln Laboratory*	$1,066.3 million
SMART*	$45.3 million
Total	**$1,885.5 million**

*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. As of June 30, 2019, there were 3,237 active awards and 520 unique consortium sponsors.

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.

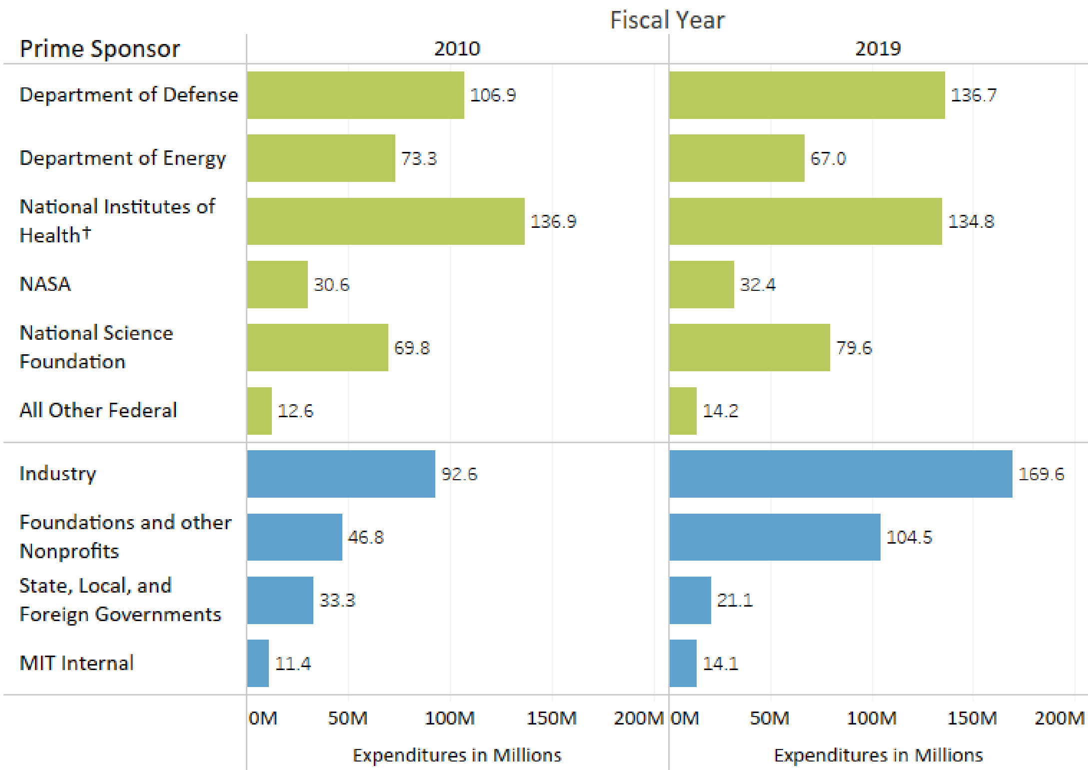
MIT Research Expenditures 1940–2019



†SMART: Singapore-MIT Alliance for Research and Technology

‡The bars represent current dollars. The red line represents Total Research in constant dollars calculated using the Consumer Price Index for all Urban Consumers weighted with fiscal year 2019 equaling 100.

Campus Research Expenditures by Prime Sponsor*



Campus Research Expenditures by Prime Sponsor

Primary Sponsor	FY2019 (In U.S. Dollars)	Percent of Campus Total
Department of Defense	136,743,404	18
Department of Energy	66,974,741	9
National Institutes of Health†	134,772,690	17
NASA	32,429,614	4
National Science Foundation	79,616,644	10
All other federal	14,180,419	2
Total Federal	**464,717,511**	**60**
Industry	169,605,879	22
Foundations and other nonprofit	104,470,528	13
State, local, and foreign governments	21,051,936	3
MIT internal	14,054,717	2
Total Non-Federal	**309,183,058**	**40**
Campus Total	**773,900,570**	**100**

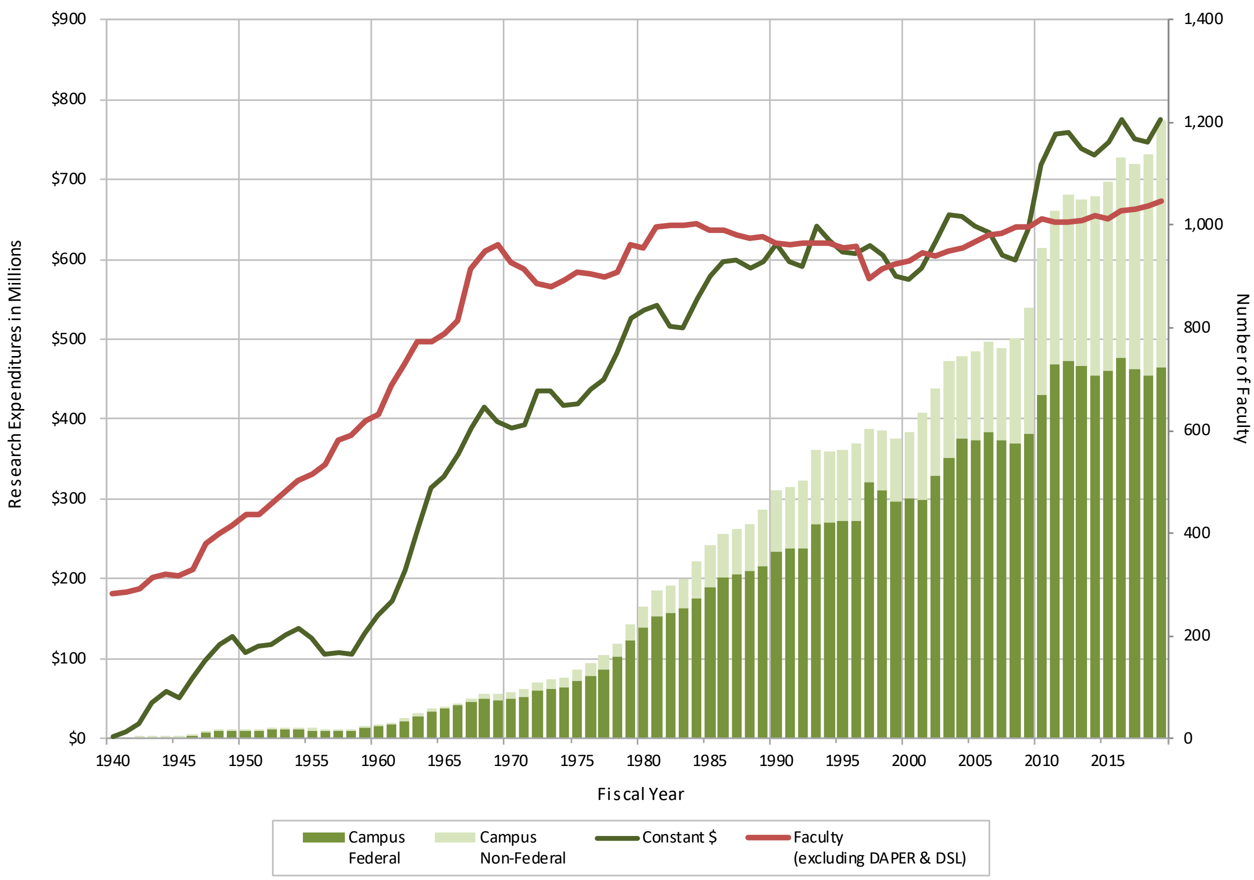
*Campus based Broad Institute research expenditures are excluded.
†National Institutes of Health data includes expenditures from other Department of Health and Human Services agencies, which account for less than 2% of expenditures per year.

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. Research Administration Services 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 Vice President for Research website.

Campus Research Expenditures by Prime Sponsor and Faculty
Excluding Broad and Defense Labs
1940–2019



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

MIT subsidizes virtually every research award that it receives, even when the award includes full indirect costs because federal funding formulas never cover the full cost of research.

Research proposal budgets include direct and indirect costs. *Direct costs* are easily attributable to individual awards and include salaries and benefits for research staff and postdocs working on the project, stipends and tuition for graduate students assigned to the award, summer salary and benefits for faculty (when they get no university salary), laboratory supplies, certain research equipment including computers, and travel and publication costs. Since most faculty are paid in full by Institutional funds during the academic year, their participation in research during this time is supported by MIT.

Indirect costs (IDC) represent genuine costs of performing research that are not easily attributable to individual awards. They are recovered in part by adding a charge to each award budget proportional to certain of the direct costs of the sponsored project. These charges are based on a fixed indirect cost rate, also known as the F&A (*facilities and administrative*) rate. Think of these charges as paying for things that wouldn't need to exist or be used as extensively if MIT didn't conduct research. Examples include depreciation of research equipment and buildings, laboratory utilities (heat/cooling, power), hazardous chemical management, insurance, administrative services, internet, and compliance with federal, state, and local regulations. The indirect cost rate is determined by dividing all the allowable indirect costs by the direct costs of all sponsored research, after excluding certain direct costs per federal regulations. The federal government defines what indirect costs can be recovered and which direct costs can be included in the total, but the indirect cost rate for research applies to all sponsors.

Each university's indirect cost rate is set based on their actual indirect costs in previous years, which are apportioned to various activities—research, instruction, or other. MIT's rates are negotiated with, and audited by, the federal government each year. MIT's IDC rate for FY2018 was 59.0%. (It was 55.0% in FY19 and is 50.6% for FY20)

A 59% indirect cost rate does not mean that 59 cents of every research dollar goes to indirect costs. The 59% rate is applied only to allowable direct costs that are subject to F&A reimbursement, not all cost. Additionally, in 1991, the government implemented a 26% rate cap applied to the administrative costs portion of the F&A rate calculations. MIT has historically been under this cap.

Figure 1 illustrates how the average federal research dollar is spent at MIT. In FY18, 72 cents of every MIT research dollar went to direct costs and 28 cents to indirect.

Figure 1. The MIT "Dollar Bill" that graphically explains how every dollar of an MIT federal research grant in FY18 is apportioned between direct and indirect costs.

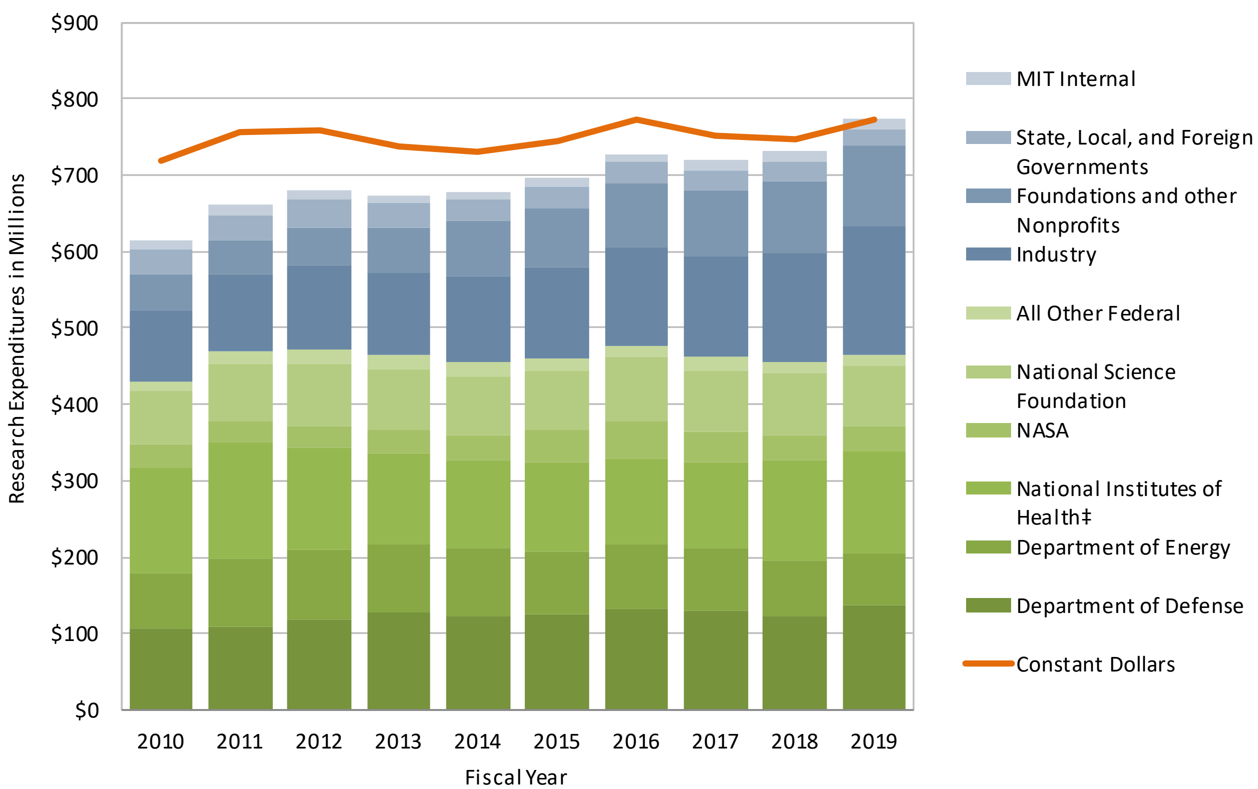
Whenever a sponsor pays less than the federally negotiated sponsored research F&A, it generates under-recovery. Some institutions do not accept awards unless they carry full indirect costs, some write off the differential centrally, and MIT, almost uniquely, identifies internal funds to fully cover the difference on a project by project basis.

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 75. 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 by Prime Sponsor (in thousands of U.S. Dollars)*
Fiscal Years 2010–2019

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Federal	430,154	469,521	472,583	465,947	454,939	459,979	477,169	461,626	454,497	464,718
Non-federal	184,216	191,305	208,497	208,402	223,473	236,912	250,985	257,880	277,012	309,183
Total	**614,371**	**660,825**	**681,079**	**674,348**	**678,412**	**696,891**	**728,154**	**719,506**	**731,509**	**773,901**
Constant dollars†	717,930	757,014	758,008	738,229	731,256	745,746	773,972	750,966	746,668	773,901



*Campus based Broad Institute research expenditures are excluded.

†Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2019 equaling 100.

‡National Institutes of Health data includes expenditures from other Department of Health and Human Services agencies which account for less than 2% of expenditures per year.

Department of Defense (DoD)

Selected projects funded by the DoD

Energy monitor can find electrical failures before they happen

A new system devised by MIT researchers can monitor the behavior of all electric devices within a building, ship, or factory, determining which ones are in use at any given time and whether any are showing signs of an imminent failure. When tested on a Coast Guard cutter, the system pinpointed a motor with burnt-out wiring that could have led to a serious onboard fire.

The new sensor, whose readings can be monitored on an easy-to-use graphic display called a NILM (non-intrusive load monitoring) dashboard, is described in *IEEE Transactions on Industrial Informatics*, in a paper by professor Steven Leeb, recent graduate Andre Aboulian MS '18, and seven others at MIT, the U.S. Coast Guard, and the U.S. Naval Academy.

The system uses a sensor that simply is attached to the outside of an electrical wire at a single point, without requiring any cutting or splicing of wires. From that single point, it can sense the flow of current in the adjacent wire, and detect the distinctive "signatures" of each motor, pump, or piece of equipment in the circuit by analyzing tiny, unique fluctuations in the voltage and current whenever a device switches on or off. The system can also be used to monitor energy usage, to identify possible efficiency improvements and determine when and where devices are in use or sitting idle.

https://bit.ly/2YfgMi0

Painting a fuller picture of how antibiotics act

Most antibiotics work by interfering with critical functions such as DNA replication or construction of the bacterial cell wall. These mechanisms represent only part of the full picture of how antibiotics act.

In a new study of antibiotic action, MIT researchers developed a new machine-learning approach to discover an additional mechanism that helps some antibiotics kill bacteria. This secondary mechanism involves activating the bacterial metabolism of nucleotides that the cells need to replicate their DNA.

Professor James Collins is senior author and research scientist Jason Yang is the lead author of the paper, which appears in *Cell*.

Many other researchers have used machine-learning models to analyze data by training an algorithm to generate predictions based on experimental data. However, these models are typically "black-box," meaning that they don't reveal the mechanisms that underlie their predictions. The MIT team took a "white-box" machine-learning approach. Before they began their computer modeling, the researchers performed hundreds of experiments to generate an array of "metabolic states" data. Then, they fed these states into a machine-learning algorithm, which was able to identify links between the different states and the outcomes of antibiotic treatment.

The "white-box" modeling approach used in this study could also be useful for studying how different types of drugs affect diseases such as cancer, diabetes, or neurodegenerative diseases, the researchers say.

https://bit.ly/2WATPVd

Spotting objects amid clutter

A new MIT-developed technique enables robots to quickly identify objects hidden in a three-dimensional cloud of data, reminiscent of how some people can make sense of a densely patterned "Magic Eye" image if they observe it in just the right way.

Robots typically "see" their environment through sensors that collect and translate a visual scene into a matrix of dots. Conventional techniques that try to pick out objects from such clouds of dots, or point clouds, can do so with either speed or accuracy, but not both. With their new technique, the researchers say a robot can accurately pick out an object within a dense cloud of dots, within seconds of receiving the visual data.

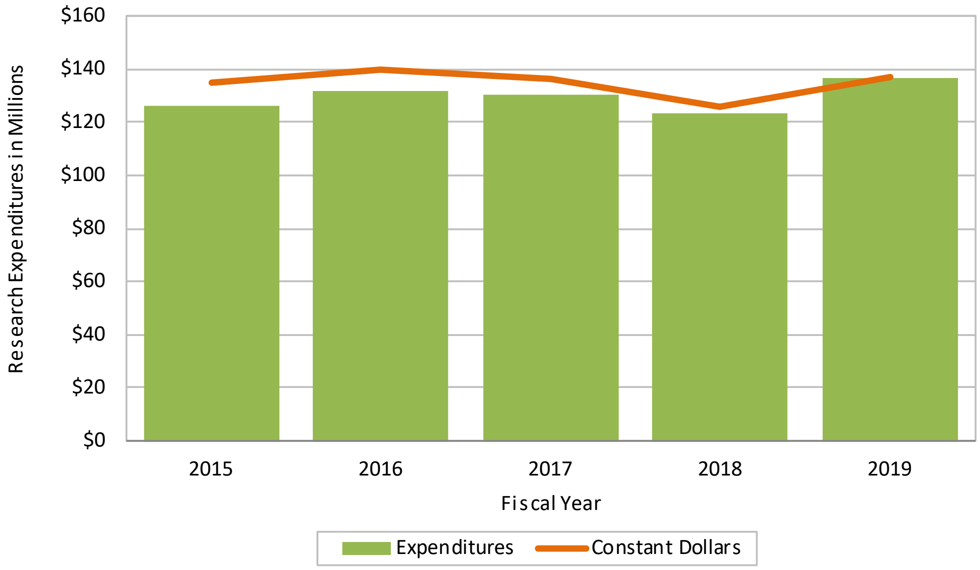
The researchers developed a three-step process to match the size, position, and orientation of the object in a point cloud with the template object, while simultaneously identifying good and bad feature associations. The team says the technique can be used to improve a host of situations in which machine perception must be both speedy and accurate, including driverless cars and robotic assistants in the factory and the home.

Assistant professor Luca Carlone and graduate student Heng Yang presented the details of the technique at the Robotics: Science and Systems conference.

https://bit.ly/33KZ4FP

Campus Research Expenditures (in U.S. Dollars)
Prime Sponsor Department of Defense
Fiscal Years 2015–2019

	2015	2016	2017	2018	2019
Campus research	125,853,521	131,624,119	130,371,698	123,512,935	136,743,404
Constant dollars*	134,676,332	139,906,450	136,072,214	126,072,575	136,743,404



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2019 equaling 100.

Leading Departments, Laboratories, and Centers Receiving Support in Fiscal Year 2019
(Shown in descending order of expenditures)

Research Laboratory of Electronics
Microsystems Technology Laboratories
Computer Science and Artificial
Intelligence Laboratory
Biological Engineering
Institute for Soldier Nanotechnologies
Mechanical Engineering
Aeronautics and Astronautics
Media Laboratory
Chemical Engineering
Materials Research Laboratory

In fall 2018, the Department of Defense funded the primary appointments of graduate students with 312 research assistantships and 57 fellowships.

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

Department of Energy (DoE)

Selected projects funded by the DoE

New polymer films conduct heat instead of trapping it

Polymers are usually the go-to material for thermal insulation. Think of a silicone oven mitt, or a Styrofoam coffee cup, both manufactured from polymer materials that are excellent at trapping heat.

Now MIT engineers have flipped the picture of the standard polymer insulator, by fabricating thin polymer films that conduct heat—an ability normally associated with metals. In experiments, they found the films, which are thinner than plastic wrap, conduct heat better than ceramics and many metals, including steel.

The team's results, published in the journal *Nature Communications*, may spur the development of polymer insulators as lightweight, flexible, and corrosion-resistant alternatives to traditional metal heat conductors, for applications ranging from heat dissipating materials in laptops and cellphones, to cooling elements in cars and refrigerators.

Professor Gang Chen is a senior co-author on the paper. Other co-authors include lead author Yanfei Xu, along with Daniel Kraemer, Bai Song, Jiawei Zhou, James Loomis, Jianjian Wang, Mingda Li, Hadi Ghasemi, Xiaopeng Huang, and Xiaobo Li from MIT, and Zhang Jiang of Argonne National Laboratory.

In 2010, the team reported success in fabricating thin fibers of polyethylene that were 300 times more thermally conductive than normal polyethylene, and about as conductive as most metals. It soon became clear that, in order for polymer conductors to be used in various applications, the materials would have to be scaled up from ultrathin fibers to more manageable films. In the end, the team was able to fabricate thin films of conducting polymer, starting with a commercial polyethylene powder.

https://bit.ly/2DIvoOd

Experiments show dramatic increase in solar cell output

In any conventional silicon-based solar cell, there is an absolute limit on overall efficiency, based partly on the fact that each photon of light can only knock loose a single electron, even if that photon carried twice the energy needed to do so. But now, researchers have demonstrated a method for getting high-energy photons striking silicon to kick out two electrons instead of one, opening the door for a new kind of solar cell with greater efficiency than was thought possible.

While conventional silicon cells have an absolute theoretical maximum efficiency of about 29.1 percent conversion of solar energy, the new approach, developed over the last several years by researchers at MIT and elsewhere, could bust through that limit, potentially adding several percentage points to that maximum output. The results are described in the journal *Nature*, in a paper by graduate student Markus Einzinger, professors Moungi Bawendi and Marc Baldo, and eight others at MIT and at Princeton University.

The basic concept behind this new technology has been known for decades, and the first demonstration that the principle could work was carried out by some members of this team six years ago. But actually translating the method into a full, operational silicon solar cell took years of hard work, Baldo says.

The key to splitting the energy of one photon into two electrons lies in a class of materials that possess "excited states" called excitons, Baldo says: In these excitonic materials, "these packets of energy propagate around like the electrons in a circuit," but with quite different properties than electrons. In this case, they were going through a process called singlet exciton fission, which is how the light's energy gets split into two separate, independently moving packets of energy. The material first absorbs a photon, forming an exciton that rapidly undergoes fission into two excited states, each with half the energy of the original state.

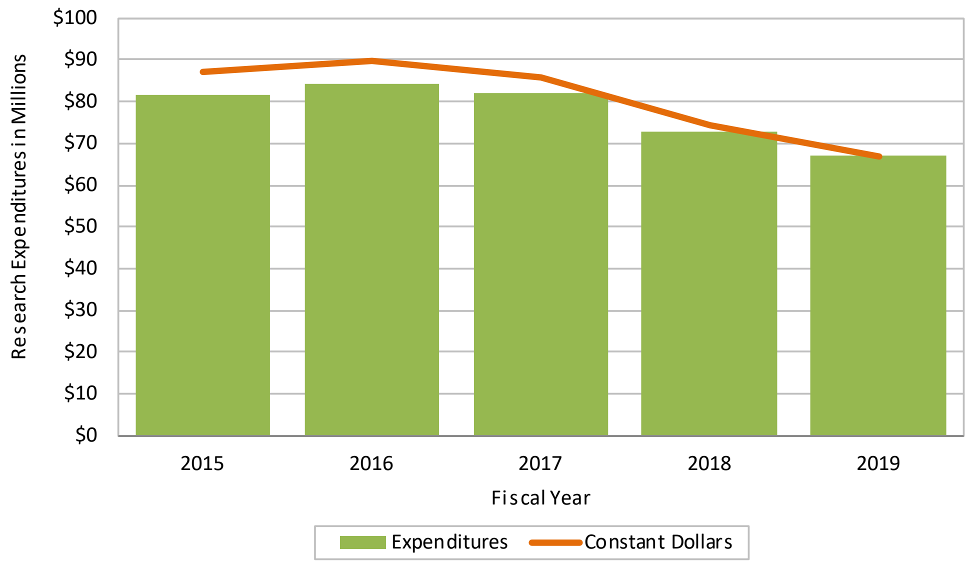
But the tricky part was then coupling that energy over into the silicon, a material that is not excitonic. This coupling had never been accomplished before.

As an intermediate step, the team tried coupling the energy from the excitonic layer into a material called quantum dots. What that work showed, Van Voorhis says, is that the key to these energy transfers lies in the very surface of the material, not in its bulk. That focus on the surface chemistry may have been what allowed this team to succeed where others had not, he suggests.

https://bit.ly/2P6C015

Campus Research Expenditures (in U.S. Dollars)
Prime Sponsor Department of Energy
Fiscal Years 2015–2019

	2015	2016	2017	2018	2019
Campus research	81,528,299	84,419,109	82,156,884	72,827,587	66,974,741
Constant dollars*	87,243,743	89,731,107	85,749,202	74,336,841	66,974,741



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2019 equaling 100.

Leading Departments, Laboratories, and Centers Receiving Support in Fiscal Year 2019
(Shown in descending order of expenditures)

Laboratory for Nuclear Science
Plasma Science and Fusion Center
Nuclear Science and Engineering
Chemical Engineering
Materials Research Laboratory
Mechanical Engineering
Chemistry
Nuclear Reactor Laboratory
Materials Science and Engineering
Research Laboratory of Electronics

In fall 2018, the Department of Energy funded the primary appointments of graduate students with 158 research assistantships and 13 fellowships.

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

National Institutes of Health (NIH)

Selected projects funded by NIH

New pill can deliver insulin

An MIT-led research team has developed a drug capsule that could be used to deliver oral doses of insulin, potentially replacing the injections that people with type 1 diabetes have to give themselves every day.

About the size of a blueberry, the capsule contains a small needle made of compressed insulin, which is injected after the capsule reaches the stomach. In tests in animals, the researchers showed that they could deliver enough insulin to lower blood sugar to levels comparable to those produced by injections given through skin. They also demonstrated that the device can be adapted to deliver other protein drugs.

Professor Robert Langer is a senior author of the study. Giovanni Traverso, an assistant professor at Brigham and Women's Hospital, Harvard Medical School, and a MIT visiting scientist, is also a senior author of the study. The first author of the paper, which appears in *Science*, is MIT graduate student Alex Abramson. The research team also includes scientists from the pharmaceutical company Novo Nordisk.

The MIT team is now continuing to work with Novo Nordisk to further develop the technology and optimize the manufacturing process for the capsules. They believe this type of drug delivery could be useful for any protein drug that normally has to be injected, such as immunosuppressants used to treat rheumatoid arthritis or inflammatory bowel disease.

https://bit.ly/2Shl2ya

Imaging system helps surgeons remove tiny ovarian tumors

Ovarian cancer is usually diagnosed only after it has reached an advanced stage, with many tumors spread throughout the abdomen. Most patients undergo surgery to remove as many of these tumors as possible, but because some are so small and widespread, it is difficult to eradicate all of them.

Researchers at MIT, working with surgeons and oncologists at Massachusetts General Hospital, have now developed a way to improve the accuracy of this surgery. Using a fluorescence imaging system, they were able to find and remove tumors as small as 0.3 millimeters—smaller than a poppy seed—during surgery in mice. Mice that underwent this type of surgery survived 40 percent longer than those who had tumors removed without the guided system.

"What's nice about this system is that it allows for real-time information about the size, depth, and distribution of tumors," says Professor Angela Belcher. The researchers are now seeking FDA approval for a phase 1 clinical trial to test the imaging system in human patients. In the future, they hope to adapt the system for monitoring patients at risk for tumor recurrence, and eventually for early diagnosis of ovarian cancer, which is easier to treat if it is caught earlier.

Professor Angela Belcher and Michael Birrer, formerly the director of medical gynecologic oncology at MGH and now the director of the O'Neal Comprehensive Cancer Center at the University of Alabama at Birmingham, are the senior authors of the study, published online in the journal *ACS Nano*.

https://bit.ly/2IKgCuC

New material could make it easier to remove colon polyps

More than 15 million colonoscopies are performed in the United States every year, and in at least 20 percent of those, gastroenterologists end up removing precancerous growths from the colon. Eliminating these early-stage lesions, known as polyps, is the best way to prevent colon cancer from developing.

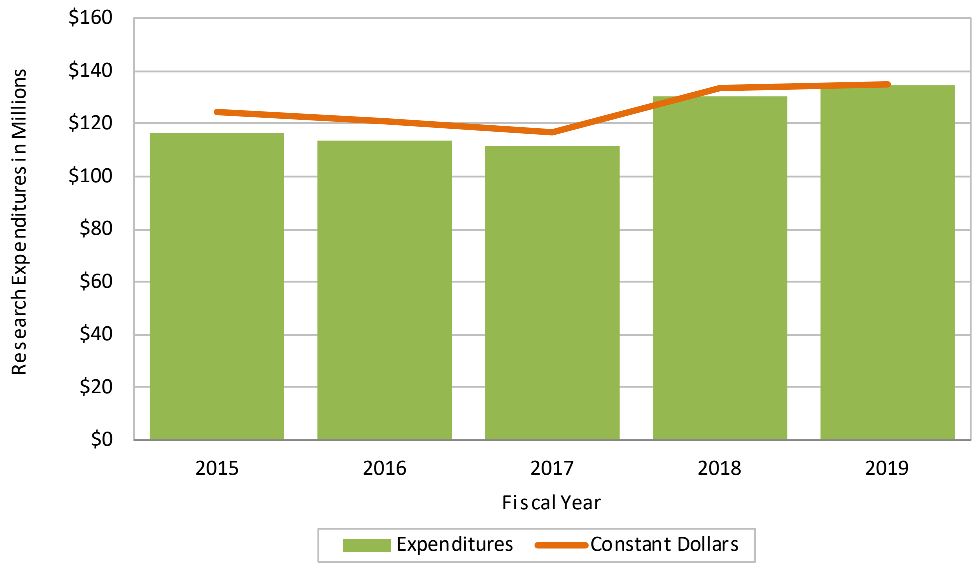
To reduce the risk of tearing the colon during this procedure, doctors often inject a saline solution into the space below the lesion, forming a "cushion" that lifts the polyp so that it's easier to remove safely. However, this cushion doesn't last long. MIT researchers have now devised an alternative—a solution that can be injected as a liquid but turns into a solid gel once it reaches the tissue, creating a more stable and longer-lasting cushion.

"That really makes a huge difference to the gastroenterologist who is performing the procedure, to ensure that there's a stable area that they can then resect using endoscopic tools," says assistant professor Giovanni Traverso and a gastroenterologist at Brigham and Women's Hospital. Traverso is the senior author of the study, which appears in *Advanced Science*.

https://bit.ly/2Mv7lZgI

Campus Research Expenditures (in U.S. Dollars)
Prime Sponsor National Institutes of Health*
Fiscal Years 2015–2019

	2015	2016	2017	2018	2019
Campus research	116,469,457	113,562,813	111,834,707	130,668,192	134,772,690
Constant dollars†	124,634,409	120,708,653	116,724,691	133,376,115	134,772,690



*Campus based Broad Institute research expenditures are excluded. National Institutes of Health data includes expenditures from other Department of Health and Human Services agencies which account for less than 2% of expenditures per year.
†Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2018 equaling 100.

Leading Departments, Laboratories, and Centers Receiving Support in Fiscal Year 2019
(Shown in descending order of expenditures)

Koch Institute for Integrative Cancer Research
Picower Institute for Learning and Memory
Biology
McGovern Institute for Brain Research
Institute for Medical Engineering and Science
Biological Engineering
Center for Environmental Health Sciences
Chemistry
Media Laboratory
Computer Science and Artificial Intelligence Laboratory

In fall 2018, the National Institutes of Health funded the primary appointments of graduate students with 174 research assistantships and 17 fellowships.

Eight current faculty have received the NIH Director's Pioneer Award. The recipients are Edward Boyden, Emery Brown, Arup Chakraborty, James Collins, Nancy Kanwisher, Aviv Regev, Kay Tye, and Feng Zhang.

NASA

Selected projects funded by NASA

MIT and NASA engineers demonstrate a new kind of airplane wing

A team of engineers has built and tested a radically new kind of airplane wing, assembled from hundreds of tiny identical pieces. The wing can change shape to control the plane's flight, and could provide a significant boost in aircraft production, flight, and maintenance efficiency, the researchers say.

The new approach to wing construction could afford greater flexibility in the design and manufacturing of future aircraft. The new wing design was tested in a NASA wind tunnel and is described in a paper in the journal *Smart Materials and Structures*, co-authored by research engineer Nicholas Cramer at NASA Ames in California; MIT alumnus Kenneth Cheung SM '07 PhD '12, now at NASA Ames; Benjamin Jenett, a graduate student; and eight others.

Instead of requiring separate movable surfaces such as ailerons to control the roll and pitch of the plane, as conventional wings do, the new assembly system makes it possible to deform the whole wing, or parts of it, by incorporating a mix of stiff and flexible components in its structure. The tiny subassemblies, which are bolted together to form an open, lightweight lattice framework, are then covered with a thin layer of similar polymer material as the framework.

The result is a wing that is much lighter, and thus much more energy efficient, than those with conventional designs, the researchers say. Because the structure, comprising thousands of tiny triangles of matchstick-like struts, is composed mostly of empty space, it forms a mechanical "metamaterial" that combines the structural stiffness of a rubber-like polymer and the extreme lightness and low density of an aerogel.

The same system could be used to make other structures as well, Jenett says, including the wing-like blades of wind turbines, where the ability to do on-site assembly could avoid the problems of transporting ever-longer blades. Similar assemblies are being developed to build space structures, and could eventually be useful for bridges and other high performance structures.

https://bit.ly/2FGARW1

TESS discovers three new planets nearby, including temperate "sub-Neptune"

NASA's MIT-developed Transiting Exoplanet Survey Satellite, or TESS, has discovered three new worlds that are among the smallest, nearest exoplanets known to date. The planets orbit a star just 73 light-years away and include a small, rocky super-Earth and two sub-Neptunes—planets about half the size of our own icy giant.

The sub-Neptune furthest out from the star appears to be within a "temperate" zone, meaning that the very top of the planet's atmosphere is within a temperature range that could support some forms of life. However, scientists say the planet's atmosphere is likely a thick, ultradense heat trap that renders the planet's surface too hot to host water or life.

Nevertheless, this new planetary system, which astronomers have dubbed TOI-270, is proving to have other curious qualities. For instance, all three planets appear to be relatively close in size. There's nothing in our solar system that resembles an intermediate planet, with a size and composition somewhere in the middle of Earth and Neptune. But TOI-270 appears to host two such planets: both sub-Neptunes are smaller than our own Neptune and not much larger than the rocky planet in the system.

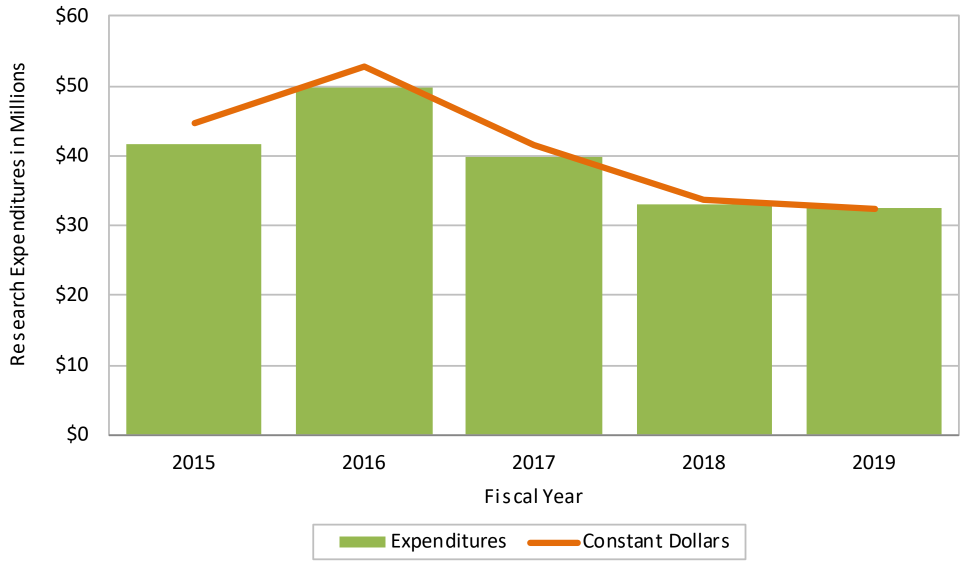
Astronomers believe TOI-270's sub-Neptunes may be a "missing link" in planetary formation, as they are of an intermediate size and could help researchers determine whether small, rocky planets like Earth and more massive, icy worlds like Neptune follow the same formation path or evolve separately.

"There are a lot of little pieces of the puzzle that we can solve with this system," says postdoc Maximilian Günther, lead author of a study published in *Nature Astronomy* that details the discovery. "You can really do all the things you want to do in exoplanet science, with this system."

https://bit.ly/2zcT1vS

Campus Research Expenditures (in U.S. Dollars)
Prime Sponsor NASA
Fiscal Years 2015–2019

	2015	2016	2017	2018	2019
Campus research	41,739,692	49,663,884	39,808,538	33,023,532	32,429,614
Constant dollars*	44,665,803	52,788,940	41,549,171	33,707,900	32,429,614



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2019 equaling 100.

Leading Departments, Laboratories, and Centers Receiving Support in Fiscal Year 2019
(Shown in descending order of expenditures)

Kavli Institute for Astrophysics and Space Research
Earth, Atmospheric and Planetary Sciences
Aeronautics and Astronautics
Haystack Observatory
Center for Global Change Science
Civil and Environmental Engineering
Research Laboratory of Electronics
Mechanical Engineering
Computer Science and Artificial
Intelligence Laboratory
Koch Institute for Integrative Cancer Research

In fall 2018, NASA funded the primary appointments of graduate students with 53 research assistantships and 16 fellowships.

National Science Foundation (NSF)

Selected projects funded by NSF

Robots track moving objects with unprecedented precision

A novel system developed at MIT uses RFID tags to help robots home in on moving objects with unprecedented speed and accuracy. The system could enable greater collaboration and precision by robots working on packaging and assembly, and by swarms of drones carrying out search-and-rescue missions.

In a paper presented at the USENIX Symposium on Networked Systems Design and Implementation, the researchers show that robots using the system can locate tagged objects within 7.5 milliseconds, on average, and with an error of less than a centimeter.

In the system, called TurboTrack, an RFID (radio-frequency identification) tag can be applied to any object. A reader sends a wireless signal that reflects off the RFID tag and other nearby objects, and rebounds to the reader. An algorithm sifts through all the reflected signals to find the RFID tag's response. Final computations then leverage the RFID tag's movement—even though this usually decreases precision—to improve its localization accuracy.

Graduate student Zhihong Luo is first author of the paper. The other Media Lab co-authors on the paper are visiting student Qiping Zhang, postdoc Yunfei Ma, and Research Assistant Manish Singh.

https://bit.ly/2TcqqCx

Working out makes hydrogels perform more like muscle

Human skeletal muscles have a unique combination of properties that materials researchers seek for their own creations. They're strong, soft, full of water, and resistant to fatigue. A new study by MIT researchers has found one way to give synthetic hydrogels this total package of characteristics: putting them through a vigorous workout.

In particular, the scientists mechanically trained the hydrogels by stretching them in a water bath. And just as with skeletal muscles, the reps at the "gym" paid off. The training aligned nanofibers inside the hydrogels to produce a strong, soft, and hydrated material that resists breakdown or fatigue over thousands of repetitive movements.

The polyvinyl alcohol (PVA) hydrogels trained in the experiment are well-known biomaterials that researchers use for medical implants, drug coatings, and other applications, says Associate Professor Xuanhe Zhao. "But one with these four important properties has not been designed or manufactured until now."

In their paper, published in the *Proceedings of the National Academy of Sciences*, Zhao and his colleagues describe how the hydrogels also can be 3D-printed into a variety of shapes that can be trained to develop the suite of muscle-like properties.

In the future, the materials might be used in implants such as "heart valves, cartilage replacements, and spinal disks, as well as in engineering applications such as soft robots," Zhao says.

https://bit.ly/2NoPLpw

Study demonstrates seagrass' strong potential for curbing erosion

Most people's experience with seagrass, if any, amounts to little more than a tickle on their ankles while wading in shallow coastal waters. But it turns out these ubiquitous plants, varieties of which exist around the world, could play a key role in protecting vulnerable shores as they face onslaughts from rising sea levels.

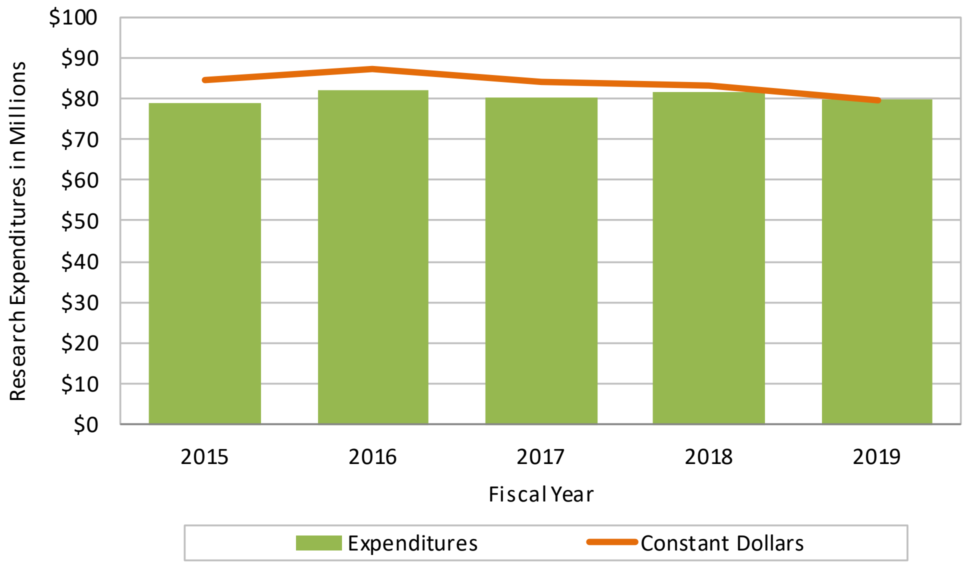
New research for the first time quantifies, through experiments and mathematical modelling, just how large and how dense a continuous meadow of seagrass must be to provide adequate damping of waves in a given geographic, climatic, and oceanographic setting.

In a pair of papers appearing in two research journals, *Coastal Engineering* and the *Journal of Fluids and Structures*, professor Heidi Nepf and doctoral student Jiarui Lei describe their findings and the significant environmental benefits seagrass offers. These include not only preventing beach erosion and protecting seawalls and other structures, but also improving water quality and sequestering carbon to help limit future climate change.

https://bit.ly/2H3Dzpa

Campus Research Expenditures (in U.S. Dollars)
Prime Sponsor National Science Foundation
Fiscal Years 2015–2019

	2015	2016	2017	2018	2019
Campus research	78,952,919	82,160,804	80,410,343	81,563,231	79,616,644
Constant dollars*	84,487,819	87,330,700	83,926,294	83,253,519	79,616,644



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2019 equaling 100.

Leading Departments, Laboratories, and Centers Receiving Support in Fiscal Year 2019
(Shown in descending order of expenditures)

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

In fall 2018, the National Science Foundation (NSF) funded the primary appointments of graduate students with 217 research assistantships. In the 2018–2019 academic year, NSF supported, at least in part, 391 students through fellowships.

The National Science Foundation has awarded Faculty Early Career Development (CAREER) Awards to 179 current faculty and staff members.

Other Federal Agencies

Selected projects funded by other federal agencies

Deep-learning technique reveals "invisible" objects in the dark

Small imperfections in a wine glass or tiny creases in a contact lens can be tricky to make out, even in good light. In almost total darkness, images of such transparent features or objects are nearly impossible to decipher. But now, engineers at MIT have developed a technique that can reveal these "invisible" objects, in the dark.

In a study published in *Physical Review Letters*, the researchers reconstructed transparent objects from images of those objects, taken in almost pitch-black conditions. They did this using a "deep neural network," a machine-learning technique that involves training a computer to associate certain inputs with specific outputs—in this case, dark, grainy images of transparent objects and the objects themselves.

The team trained a computer to recognize more than 10,000 transparent glass-like etchings, based on extremely grainy images of those patterns. The images were taken in very low lighting conditions, with about one photon per pixel—far less light than a camera would register in a dark, sealed room. They then showed the computer a new grainy image, not included in the training data, and found that it learned to reconstruct the transparent object that the darkness had obscured.

The results demonstrate that deep neural networks may be used to illuminate transparent features such as biological tissues and cells, in images taken with very little light.

George Barbastathis is a co-author on the paper with lead author Alexandre Goy, Kwabena Arthur, and Shuai Li.

https://bit.ly/2Ev5XSi

Shift to renewable electricity a win-win at statewide level

Amid rollbacks of the Clean Power Plan and other environmental regulations at the federal level, several U.S. states, cities, and towns have resolved to take matters into their own hands and implement policies to promote renewable energy and reduce greenhouse gas emissions. One popular approach, now in effect in 29 states and the District of Columbia, is to set Renewable Portfolio Standards (RPS), which require electricity suppliers to source a designated percentage of electricity from available renewable-power generating technologies.

Boosting levels of renewable electric power not only helps mitigate global climate change, but also reduces local air pollution. Quantifying the extent to which this approach improves air quality could help legislators better assess the pros and cons of implementing policies such as RPS. Toward that end, a research team at MIT has developed a new modeling framework that combines economic and air-pollution models to assess the projected subnational impacts of RPS and carbon pricing on air quality and human health, as well as on the economy and on climate change. In a study focused on the U.S. Rust Belt, their assessment showed that the financial benefits associated with air quality improvements from these policies would more than pay for the cost of implementing them. The results appear in the journal *Environmental Research Letters*. The study's lead author is senior research associate Emil Dimanchev. MIT Associate Professor Noelle Selin led the study.

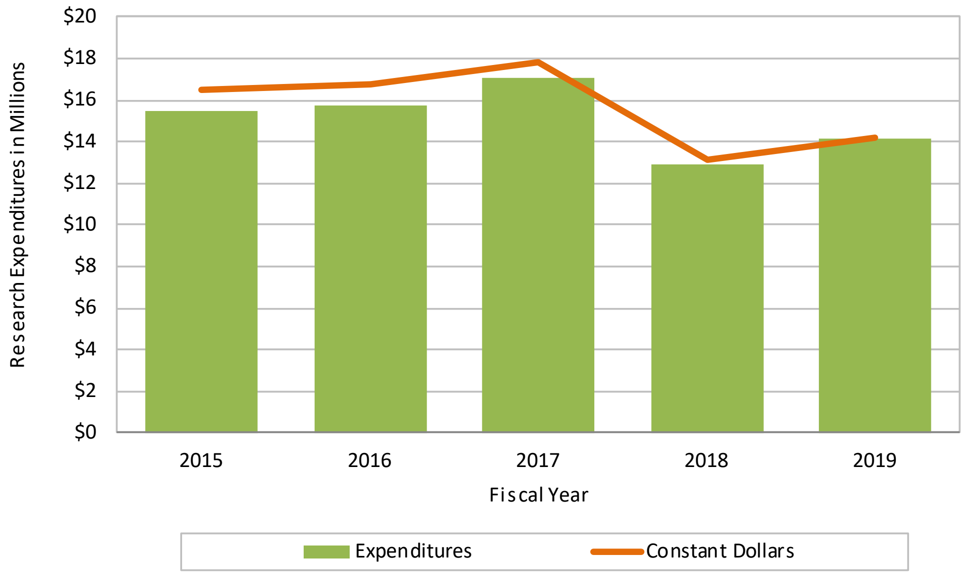
Burning fossil fuels for energy generation results in air pollution in the form of fine particulate matter (PM2.5). Exposure to PM2.5 can lead to adverse health effects. But avoiding those health effects—and the medical bills, lost income, and reduced productivity that comes with them—through the adoption of cleaner energy sources translates into significant cost savings, known as health co-benefits.

Applying their modeling framework, the MIT researchers estimated that existing RPS in the nation's Rust Belt region generate a health co-benefit of $94 per ton of carbon dioxide (CO2) reduced in 2030, or 8 cents for each kilowatt hour (kWh) of renewable energy deployed in 2015 dollars. Their central estimate is 34 percent larger than total policy costs. The team also determined that carbon pricing delivers a health co-benefit of $211 per ton of CO2 reduced in 2030, 63 percent greater than the health co-benefit of reducing the same amount of CO2 through an RPS approach. The MIT research team's results are consistent with previous studies, which found that the health co-benefits of climate policy (including RPS and other instruments) tend to exceed policy costs.

https://bit.ly/2Z3NMsN

Campus Research Expenditures (in U.S. Dollars)
Prime Sponsor Other Federal Agencies
Fiscal Years 2015–2019

	2015	2016	2017	2018	2019
Campus research	15,435,252	15,738,434	17,043,458	12,901,728	14,180,419
Constant dollars*	16,517,322	16,728,761	17,788,685	13,169,099	14,180,419



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2019 equaling 100.

A few of the leading other federal agencies providing funding are the U.S. Department of Commerce, the U.S. Agency for International Development, the U.S. Department of Interior, the Federal Aviation Administration, the Intelligence Advanced Research Projects Activity (IARPA), and the U.S. Department of Transportation.

Leading Departments, Laboratories, and Centers Receiving Support in Fiscal Year 2019
(Shown in descending order of expenditures)

Mechanical Engineering
Center for Transportation and Logistics
Aeronautics and Astronautics
Computer Science and Artificial Intelligence Laboratory
Civil and Environmental Engineering
Office of Experiential Learning
Materials Research Laboratory
Center for Global Change Science
Laboratory for Information and Decision Systems
Earth, Atmospheric and Planetary Sciences

In fall 2018, other federal agencies funded the primary appointments of graduate students with 38 research assistantship.

Nonprofit Organizations

Selected projects funded by nonprofit organizations

Reducing the burden of tuberculosis treatment

Tuberculosis is one of the world's deadliest infectious diseases: One-third of the world's population is infected with TB, and more than 1 million people die from the disease every year.

One reason TB is so pervasive is that treatment requires a six-month course of daily antibiotics, which is difficult for about half of all patients to adhere to, especially in rural areas with limited access to medical facilities. To help overcome that, a team of researchers led by MIT has devised a new way to deliver antibiotics, which they hope will make it easier to cure more patients and reduce health care costs.

Using this new approach, a coiled wire loaded with antibiotics is inserted into the patient's stomach through a nasogastric tube. Once in the stomach, the device slowly releases antibiotics over one month, eliminating the need for patients to take pills every day.

Assistant professor Giovanni Traverso, a gastroenterologist at Brigham and Women's Hospital, and Professor Robert Langer are the senior authors of the study, which appears in *Science Translational Medicine*. The paper's lead author is MIT graduate student Malvika Verma; the team includes others at MIT, as well as from Harvard Medical School, Boston University School of Public Health, several hospitals in India, and the Tata Trusts of Mumbai, India.

https://bit.ly/2TKGfR3

Brain wave stimulation may improve Alzheimer's symptoms

By exposing mice to a unique combination of light and sound, MIT neuroscientists have shown that they can improve cognitive and memory impairments similar to those seen in Alzheimer's patients.

This noninvasive treatment, which works by inducing brain waves known as gamma oscillations, also greatly reduced the number of amyloid plaques found in the brains of these mice. Plaques were cleared in large swaths of the brain, including areas critical for cognitive functions such as learning and memory.

"When we combine visual and auditory stimulation for a week, we see the engagement of the prefrontal cortex and a very dramatic reduction of amyloid," says Li-Huei Tsai, director of MIT's Picower Institute for Learning and Memory and the senior author of the study.

Further study will be needed, she says, to determine if this type of treatment will work in human patients. The researchers have already performed some preliminary safety tests of this type of stimulation in healthy human subjects.

MIT graduate student Anthony Martorell and Georgia Tech graduate student Abigail Paulson are the lead authors of the study, which appears in *Cell*.

https://bit.ly/2CiAeB2

A better way to encapsulate islet cells for diabetes treatment

When medical devices are implanted in the body, the immune system often attacks them, producing scar tissue around the device, known as fibrosis, which can interfere with the device's function.

MIT researchers have now come up with a novel way to prevent fibrosis from occurring, by incorporating a crystallized immunosuppressant drug into devices. After implantation, the drug is slowly secreted to dampen the immune response in the area immediately surrounding the device.

"We developed a crystallized drug formulation that can target the key players involved in the implant rejection, suppressing them locally and allowing the device to function for more than a year," says Shady Farah, an MIT and Boston Children's Hospital postdoc and co-first author of the study.

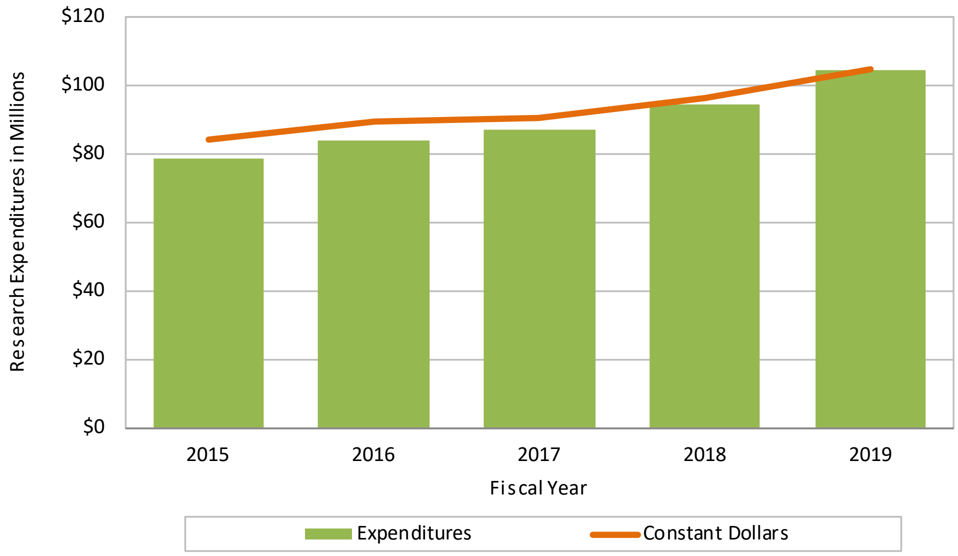
The researchers showed that these crystals could dramatically improve the performance of encapsulated islet cells, which they are developing as a possible treatment for patients with type 1 diabetes. Such crystals could also be applied to a variety of other implantable medical devices, such as pacemakers, stents, or sensors.

Former MIT postdoc Joshua Doloff, now an assistant professor at Johns Hopkins University School of Medicine, is also a lead author of the paper, which appears in *Nature Materials*. Daniel Anderson, an MIT associate professor, is the senior author of the paper.

https://bit.ly/2L0yjof

Campus Research Expenditures (in U.S. Dollars)
Prime Sponsor Nonprofit Organizations
Fiscal Years 2015–2019

	2015	2016	2017	2018	2019
Campus research	78,666,639	84,015,000	86,752,718	94,322,337	104,470,528
Constant dollars*	84,181,469	89,301,570	90,545,990	96,277,041	104,470,528



*Constant dollars are calculated using the Consumer Price Index for All Urban Consumers weighted with the fiscal year 2019 equaling 100.

Leading Departments, Laboratories, and Centers Receiving Support in Fiscal Year 2019
(Shown in descending order of expenditures)

Koch Institute for Integrative Cancer Research
Economics
Biology
Computer Science and Artificial Intelligence Laboratory
Mechanical Engineering
McGovern Institute for Brain Research
Civil and Environmental Engineering
Research Laboratory of Electronics
Media Laboratory
Biological Engineering